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BEFORE THE
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

IN RE APPLICATION FOR A FUEL ADDITIVE WAIVER FILED BY ETHYL CORPORATION UNDER § 211(f)(4) OF THE CLEAN AIR ACT	)))))))

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APPENDICES TO THE WAIVER APPLICATION
FOR THE HiTEC 3000 PERFORMANCE ADDITIVE

VOLUME TWO

APPENDICES 3, 4 AND 5

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HiTEC 3000 WAIVER APPLICATION APPENDICES

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APPENDIX 3

DURABILITY TESTING, MATERIALS COMPATIBILITY TESTING, EVAPORATIVE EMISSIONS, DRIVEABILITY, AND PARTICULATE EMISSIONS

Introduction

HiTEC® 3000 Performance Additive ("HiTEC 3000") has been used successfully in Canadian unleaded gasoline for over a decade. During that time there have been no confirmed reports of problems with fuel stability, compatibility with materials or durability of engine components associated with the use of the HiTEC 3000 additive in unleaded gasoline. This demonstration of proven reliability occurred while the concentration of the HiTEC 3000 additive in Canadian unleaded gasolines averaged 0.045 to 0.050 g Mn/USG (12 to 13 mg/L), over 50% higher than the concentration of 0.03125 g Mn/USG (8 mg Mn/L) applied for in this waiver application. Some Canadian gasolines reached the maximum allowable manganese concentration of 0.068 g/USG (18 mg/L) without causing engine or emission control problems.

While the HiTEC 3000 additive's proven record in Canada demonstrates that the HiTEC 3000 additive does not adversely impact the durability of vehicle exhaust systems, the materials used in vehicle fuel systems, evaporative emissions, or driveability, Ethyl Corporation ("Ethyl") conducted additional laboratory tests and analyses of the test fleet results to confirm that the HiTEC 3000 additive does not adversely affect these aspects of car operation. This Appendix describes, and provides the results of, these additional tests and analyses.

A. DURABILITY OF EMISSION CONTROL SYSTEMS COMPONENTS

To determine what impact, if any, use of the HiTEC 3000 additive would have on the durability of emission control system components, Ethyl completed the following investigations:

(1) Reliability of oxygen sensors from the test fleet.

(2) Catalytic converter efficiencies for test fleet cars at 50,000 and 75,000 miles.

(3) Back pressure variations on catalytic converters in the test fleet at 75,000 miles.

(4) Catalytic converter plugging tendencies under high speed conditions.

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(2) Catalytic converter efficiencies for test fleet cars at 50,000 and 75,000 miles.

(3) Back pressure variations on catalytic converters in the test fleet at 75,000 miles.

(4) Catalytic converter plugging tendencies under high speed conditions.

(5) Extended durability of engine and emission system components after 100,000 miles of vehicle operation.

The results of these investigations are detailed in the following sections.

1. Reliability of Oxygen Sensors

Oxygen sensors are located in the exhaust system to control the fuel flow in order to provide the correct air/fuel ratio to the engine. Improper operation of the oxygen sensor can lead to excessive exhaust emissions and/or faulty engine performance. The test results summarized in Attachment 3-1, with data on individual car models in Attachments 3-2 through 3-9, show that use of the HiTEC 3000 additive has no deleterious effects on the performance of oxygen sensors.

A series of evaluations was undertaken to determine if the HiTEC 3000 additive has any effect on the performance of oxygen sensors. After all cars of a model group in the test fleet had reached 50,000 miles, and the necessary emission tests for that mileage had been completed satisfactorily, the oxygen sensors were carefully removed from each car. A car from each model group fueled with clear Howell EEE and which gave the most repeatable emission ratings was selected as the "test bed" vehicle. It was used as the common source of engine emissions for comparing the performance of all the oxygen sensors from that model group. The oxygen sensors in those "test bed" vehicles were replaced in sequence with sensors from the other cars of like model in the test fleet. Tailpipe emissions were then measured. A new oxygen sensor was also tested in 6 of the 8 "test bed" vehicles to provide a 50,000-mile base for oxygen sensor performance.

The mean differences in emissions between the sensors operated on the HiTEC 3000 additive and those operated on Howell EEE clear fuel are presented in Attachment 3-1 for the various car models. There is no significant difference between the two fuel groups of sensors at the 95% confidence level as determined by the standard t-test statistical method.

The detailed emission data for the individual sensors, along with the 3-car average for each fuel, are presented in Attachments 3-2 through 3-9 for the various car models. The lower part of the tables contain the mean differences of the emission measurements for the two fuels, along with the "upper" and "lower" 95% confidence interval as calculated by the standard t-test. Since the spread in confidence intervals between the two fuels includes the numeral zero, the indicated difference is not statistically significant at the 95% confidence level. This is true for all 8 car models. Thus, the HiTEC 3000 additive does not affect the performance of oxygen sensors.

This conclusion is supported by comparing the 50,000-mile, 3-car average sensor data with those obtained with a new sensor. These data, presented in Attachment 3-10, show that sensors operated 50,000 miles on the HiTEC 3000 additive gave lower HC, CO, and NOx emissions than obtained with new sensors. Sensors operated 50,000 miles on Howell EEE clear fuel gave, on average, lower HC emissions and slightly higher CO and NOx emissions than obtained with new sensors.

The decision to determine emission concentrations with new oxygen sensors was made after all of the testing at 50,000 miles had been completed on car models "D" and "F." These cars had returned to the test fleet and were by that time accumulating mileage toward the 75,000 mile goal. Consequently, data with new oxygen sensors are not available on models "D" and "F."

The foregoing two investigations demonstrate that the HiTEC 3000 additive does not adversely affect the operation of oxygen sensors.

2. Catalytic Converter Efficiencies for Test Fleet Cars

An automobile catalytic converter is designed to greatly reduce exhaust emissions of HC, CO and NOx. In order to determine whether the HiTEC 3000 additive had an effect on the performance of catalytic converters in cars, Ethyl conducted special tests on the test vehicles at 1,000, 50,000, and 75,000 miles of vehicle operation. In order to do this, Ethyl used the mini-type CVS unit which was developed for CVS-type measurements of engine-out emissions.[1/] The equipment to make this measurement was available at the ECS laboratories in Livonia but not at the ATL facility in South Bend.

Data reported below show that the HiTEC 3000 additive improves conversion efficiency for NOx, gives a small improvement for HC and equal conversion efficiency for CO when compared with cars operated on the control gasoline.

a. Test Protocol

The conversion efficiencies of catalysts from test vehicles fueled with the control gasoline were compared to those from vehicles fueled with the control gasoline containing the HiTEC 3000 additive. The formula to calculate conversion efficiency is:

$$\text{Conversion Efficiency} = 1 - \frac{\text{Tailpipe emissions}}{\text{Engine-out emissions}}$$

1/ J.H. Randall and R.R. Carlson, "Simultaneous Measurement of Engine-Out and Tail Pipe Mass Emissions," SAE #790705, Dearborn, MI, June 11, 1979.

All the vehicles in the test fleet accumulated mileage on only the control gasoline for the first 1,000 miles.[2] Then, conversion efficiency was determined for all cars except in Car Model "F." The complication of obtaining a good sample ahead of the close-coupled catalysts in Car Model "F" was the reason that conversion efficiency was not measured on this group of cars.

Since all vehicles were operated on the control gasoline for the first 1,000 miles, this provided a base comparison point to determine the effect of the HiTEC 3000 additive versus the control gasoline on catalyst conversion efficiency at 50,000 and 75,000 miles. However, conversion efficiency at 1,000 miles for the three cars within a model group to be operated on fuel containing the HiTEC 3000 additive could be slightly different from the conversion efficiency for the three cars operating on control gasoline. For example, cars assigned to use fuel with the HiTEC 3000 additive in Car Model "C" had an HC conversion efficiency of 90.9% compared to 91.4% for cars operating on control gasoline (Attachment 3-12). In order to compensate for this difference, Ethyl calculated the "loss in efficiency" from 1,000 miles to 50,000 and 75,000 miles, respectively.

c. Summary of Test Results

The catalytic converter performance, presented as "loss in efficiency" from the 1,000 mile point, is shown in Attachment 3-11 by model grouping. Attachment 3-11 also shows the test fleet average loss in efficiency for HC, CO, and NOx emissions. The data show that the HiTEC 3000 additive does not have a deleterious effect on catalyst conversion efficiency. In fact, the data indicate that the HiTEC 3000 additive enhances the ability of the catalyst to convert NOx emissions when compared to the control gasoline and this effect increases between 50,000 and 75,000 miles. At 50,000 miles the average loss in efficiency in connection with NOx emissions for the fleet cars operated with gasoline containing the HiTEC 3000 additive is only 5.1 percentage points as compared to a loss in efficiency of 8.3 percentage points for the cars operated on the control gasoline; a benefit in favor of the HiTEC 3000 additive of 3.2 percentage points. At 75,000 miles, this benefit from the HiTEC 3000 additive has increased to 5.1 percentage points. Ethyl believes that this benefit is due to the manganese oxides on the catalyst that assist in reducing the nitrogen oxides.[3] The HiTEC 3000 additive has a small benefit in converting HC (0.3 percentage points at 50,000 miles and 1.0 percentage points at 75,000 miles) and no apparent benefit in converting CO.

2/ Appendix 1, page 5.

3/ Appendix 9, "Catalysis of NO Decomposition by Mn_3O_4."

The actual conversion efficiency data is given in Attachments 3-12, 3-13, and 3-14 for HC, CO, and NOx, respectively. Together, these test results demonstrate that the HiTEC 3000 additive does not adversely affect the performance of catalytic converters. In fact, it substantially improves the conversion efficiency for NOx and gives a small improvement for HC emissions.

3. Exhaust System Back Pressure on Fleet Cars

Manganese in the HiTEC 3000 additive is converted primarily to Mn_3O_4 in an engine's combustion cylinders. While the quantity of manganese in gasoline is small, the question was raised as to whether manganese oxides might contribute to catalyst plugging. To determine whether the HiTEC 3000 additive tends to plug emission systems, Ethyl measured exhaust back pressure on the test cars; i.e., total pressure ahead of the catalyst. This measurement represents the restriction generated by the catalyst and the acoustic components of the exhaust system. All cars were tested for back pressure, except car model group "F," after 75,000 miles of service. Car model "F" was not tested because this models is not equipped so that a pressure gauge can be installed at the proper location.[4/]

Multiple accelerations were first made in one direction on the road. The vehicle was then turned around and multiple accelerations were made on the same road, but in the opposite direction to the first set of accelerations. Pressure on the exhaust system was measured at an engine speed of 4500 rpm, and at wide open throttle (WOT), with the data summarized in Table 3-15.

There was no statistically significant difference in exhaust system back pressure between the cars that were fueled with Howell EEE gasoline containing the HiTEC 3000 additive or clear Howell EEE. This test, along with results from the high speed testing described in the next section of this Appendix, demonstrate that HiTEC 3000 does not cause catalyst plugging.

4. Catalytic Converter Plugging Tendencies at High Speed

To determine whether use of the HiTEC 3000 additive under high speed conditions would cause catalyst plugging, Ethyl selected two 1989 Ford 5.0L Crown Victorias for the high speed testing described below. The Crown Victoria is equipped with a small close-coupled, warm-up catalyst in each bank of its Y-type exhaust system. Close-coupled catalysts are considered to be susceptible to plugging because hot exhaust gases have had only a minimal opportunity to cool before entering the catalyst, which may cause materials to deposit on the catalyst face.

4/ Appendix 3, page 4.

The cars used for this test had accumulated approximately 15,000 miles in normal rental service prior to this test. After receiving the cars, new catalysts and oxygen sensors were installed prior to starting the tests. During the test, one car operated on clear Howell EEE fuel, while the second car used Howell EEE fuel with the HiTEC 3000 additive at 0.03125 g Mn/gal.

The driving cycle was based on discussions with Ford and GM. The cycle that was used at the ATL test track is shown in Attachment 3-16. During the first 25,000 miles the top speed was 65 mph, for approximately 45% of the driving cycle. After completion of the 25,000-mile portion, the car was tuned up and the driving cycle was made more severe. The top speed was raised for 45% of the driving cycle to 80 mph from the previous level of 65 mph for 10,000 additional miles.

To determine if catalyst plugging occurred, exhaust back pressures were measured just ahead of the close-coupled catalysts at wide open throttle and 4500 rpm. Back pressure on both cars remained constant at 8 psi for both segments of the high speed testing indicating no catalyst plugging.

5. Extended Durability of Engine and Emission System Components

In an effort to determine the performance of engines and emission systems over extended mileage, four (4) Chevrolet Corsica's equipped with 2.0L engines and three-way catalytic converters were operated for 100,000 miles. These vehicles were obtained in the late summer of 1987. A pair of vehicles were operated on Howell EEE and Howell EEE plus HiTEC 3000 at a level of 0.03125 grams Mn per gallon. Test mileage was accumulated on a route of streets and roads chosen in accordance with EPA Federal Test Procedures for emission system durability. All emission testing was performed according to FTP-75 procedures with two basic exceptions:

(a) The actual emission tests were obtained using the fuel in the tank without conditioning in a diurnal soak period.

(b) Each emission test consisted of measuring tailpipe emissions with a constant volume sampler and engine-out emissions with a mini-CVS unit.

Following completion of 100,000 miles of operation, Ethyl conducted testing to compare the conversion efficiencies and the catalytic converter exhaust back pressures for the two sets of vehicles. The results of the conversion efficiency analysis are provided in Attachment 3-17. The vehicles operating on HiTEC 3000 exhibited slightly better HC conversion efficiency, equal CO conversion efficiency and dramatically improved NOx conversion efficiency.

No differences in back pressure were observed with all converters having about ten (10) inches of water pressure (measured at 55 mph and 15 horsepower on the emission chassis dynamometer). These data demonstrate that HiTEC 3000 does not adversely affect the operation of engines and emission systems.

B. MATERIALS COMPATIBILITY TESTING

To confirm that the HiTEC 3000 additive does not adversely affect materials in the vehicle fuel and emission control systems, or fuel storage systems, Ethyl conducted standardized laboratory tests to evaluate the compatibility of the HiTEC 3000 additive blended fuels with metals and non-metal materials, and the stability characteristics of these blends. The results of these tests, which are described below, show that use of the HiTEC 3000 additive in unleaded gasoline will not adversely effect the fuel, materials used in cars for fuel handling purposes or emission control systems of vehicles, or fuel storage systems.

1. Fuel Blends Used in Laboratory Tests

The base fuel used for the mileage accumulation in this program was Howell EEE gasoline. This fuel is routinely used as a standard certification and test fuel by automotive and oil companies. Specifications and an analysis of a typical batch used in the test program are given in Appendix 1, Attachment 1-3.

Although hydrocarbon blends made from refinery components are the dominant type of automotive gasoline, oxygenated fuels are increasing in importance. Consequently, blends were made with ethanol, MTBE and methanol with isopropanol as a co-solvent. These are oxygenated compounds approved by the EPA for use in unleaded gasoline. These blends with and without the HiTEC 3000 additive were run in tests to determine if the manganese had any effect on fuel stability and compatibility with metals, plastics and elastomers. Composition of the blends tested were:

Blend 1	Howell EEE
Blend 2	Howell EEE + 0.03125 g Mn/gallon
Blend 3	Howell EEE + 10% ethanol
Blend 4	Howell EEE + 10% ethanol + 0.03125 g Mn/gallon
Blend 5	Howell EEE + 15% MTBE
Blend 6	Howell EEE + 15% MTBE + 0.03125 g Mn/gallon
Blend 7	Howell EEE + 4.5% methanol + 4.5% isopropanol
Blend 8	Howell EEE + 4.5% methanol + 4.5% isopropanol + 0.03125 g Mn/gallon

Fuel compositions used in this study meet the limits on oxygen concentration as set in waivers for alcohol blends that were granted by the EPA. According to those waivers, approved corrosion inhibitors must be added when ethanol or blends of methanol with heavier alcohols are used in unleaded gasolines. These additives, Dupont Corrosion Inhibitor DCI 11 in ethanol and Dupont Corrosion Inhibitor DGOI-100 in methanol/heavier alcohol blends, were included in blends 3, 4, 7, and 8 at recommended dosages.

A single batch of each of the gasoline blends described above was made and divided for the stability and materials compatibility testing.

2. Corrosion Tests

In order to be acceptable in petroleum products, an additive must demonstrate that it will not corrode metals that are used in a vehicle's fuel handling system or in the product's distribution system. The standard procedure to evaluate corrosion characteristics is defined by the National Association of Corrosion Engineers (NACE) in their Rust Test TM-01-72.

Ethyl contracted with Cortest Engineering Services, Cypress, Texas ("Cortest") to conduct both a short-term and long-term version of NACE Rust Test TM-01-72 on the eight fuel blends cited above using the following metals: Carbon Steel 1010 grade, Aluminum cast alloy 329, Die Cast Zinc alloy metal Zimak 3, Copper 110, Admiralty brass 443, Cadmium plated steel and Terne plated steel. Additional information on these materials is given in Attachment 3-18, "Appendix, Table II - Test Materials."

(a) NACE Rust Test (TM-01-72)

The eight fresh fuel blends were evaluated for corrosivity using the seven test metals in the NACE Rust Test (TM-01-72). The results are shown in Table 2, Attachment 3-18. The purpose of this test was to learn whether the HiTEC 3000 additive causes corrosion when added to base fuel or to oxygenate-containing blends. No significant corrosion was observed and differences between base fuel and additive blends show no trends. This conclusion is also true when comparing the oxygenates with the HiTEC 3000 additive.

(b) Long-Term Metal Compatibility Test

The eight fresh fuel blends were also evaluated for corrosivity using the seven test metals in a long-term (12-week) static test simulating occasional automobile use with infrequent refills of the gas tank under relatively warm weather conditions. This test was conducted at the high ambient temperature of 100°F to maximize possible breakdown and interaction of additives and fuel components and development of corrosion. No significant corrosion was observed on any test metal.

The effect on appearance of coupons when only the HiTEC 3000 additive was added to the base fuel was not significantly different from the effect of the oxygenate blends. The metals developed no pits or areas of corrosion except for small areas on steel and here the presence of the HiTEC 3000 additive may have exerted a slight inhibiting effect on corrosion. For the non-ferrous alloys, the HiTEC 3000 additive, when added to the blends containing oxygenates, exerted no apparent trend.

Changes in metal loss as compared to the oxygenates were not of significance and were as often benign as prejudicial. The greatest weight changes were found with the cupreous alloys. In particular, the greatest loss was 1.7 mg per square centimeter for copper after four weeks of exposure to Blend 8. This amounts to a corrosion rate of only 0.00012 inches per year[5/] and more than eight years would elapse before corrosion would remove so much as 1 mil of thickness. The rates for steel and other non-cupreous alloys was less than a tenth of the rate on copper, thus showing that parts made of terne or cadmium plate, aluminum, zinc or steel would perform for eighty years with only one mil of metal loss. By industry standards these are very low corrosion rates.

3. <u>Compatibility Tests</u>

In addition to being non-corrosive to metals, an additive must be compatible with non-metals that may be present in vehicle fuel handling systems and in fuel distribution systems. Ethyl selected five elastomers and five plastics to represent the wide range of non-metals that could be present in these types of service. As with the metals, Cortest conducted the standardized tests described below to evaluate the effects, if any, of the HiTEC 3000 additive on non-metals.

The elastomers and plastics chosen by Ethyl have been thoroughly tested in hydrocarbon fuels and blends made with hydrocarbon fuels and oxygenates as is reflected in previous waiver applications by Sun Refining and Marketing Company, E.I. DuPont De Nemours and Company, Inc., and The Texas Methanol Corporation. In addition, reports by Ismat A. Abu-Isa[6/], [7/] document the effects of hydrocarbon and oxygenated compounds on elastomers. Therefore, the tests conducted by Cortest were chosen to evaluate fuels with and without the HiTEC 3000 additive for compatibility with materials.

5/ Attachment 3-18, "Appendix, Table 1 - Test Methods."

6/ Ismat A. Abu-Isa, "Elastomer-Gasoline Blends Interactions I. Effects of Methanol-Gasoline Mixtures on Elastomers," Rubber Chemistry and Technology, Vol. 56, Page 135.

7/ Ismat A. Abu-Isa, "Elastomer-Gasoline Blends Interactions II. Effects of Ethanol/Gasoline and Methyl-t-butyl Ether/ Gasoline Mixtures on Elastomers," Rubber Chemistry and Technology, Vol. 56, Page 169.

(1) Elastomers

The following elastomeric materials were tested:

Viton - Low Fluorine (A)
Viton - High Fluorine (6269)
Hydrin (Epichlorhydrin)
NBR (Acrylonitrile)
Urethane

Additional information on these materials is given in the Attachment 3-18, "Appendix, Table II - Test Materials."

Elastomers were evaluated by the following tests:

ASTM D 412, Rubber Properties in Tension. This test provides information on the tensile stress at specified elongation, tensile strength and elongation at break of test specimens.

ASTM D 471, Rubber Property - Effect of Liquids. This test determines the change in mass and change in volume of specimens after exposure to liquids.

ASTM D 2240, Rubber Property - Durometer Hardness. Data for determining the indentation hardness of homogenous materials is obtained in this test.

The eight fresh fuel blends listed on page 7, Appendix 3 were evaluated for compatibility with five elastomeric materials in a static test of twelve weeks duration simulating occasional automobile use with infrequent refills of the gas tank under relatively warm weather conditions. The test was conducted at the high ambient temperature of 110°F to maximize possible breakdown of, and interaction between, additives and fuel components to develop possible agents which might attack the elastomers. The test purpose was to compare the effects on the elastomers of the base fuel with and without the HiTEC 3000 additive and similarly to compare the effects of three oxygenate blends with and without the HiTEC 3000 additive. No significant deterioration of any elastomer was found. Most of the change in properties was due to the base fuel. On average there was slight increases in effects with oxygenates present in the base fuel. When comparing the oxygenate blends alone with those containing the HiTEC 3000 additive, no significant trends are discernible.

The evaluation of compatibility was made by determining changes in several properties at 2, 4, and 12 weeks from those measured initially. The properties measured are typically used to determine the usefulness of elastomers in applications such as fuel systems. These properties included appearance, strength, volume swell, tensile strength and flexural properties as measured by standard (ASTM) procedures. The results are similar to those reported by others, for example "Clean Air Act Waiver Application, Vol. 3, E.I. DuPont, July 11, 1984.

The largest effects on several elastomers developed when exposed to Blends 7 and 8 which contained methanol and propanol. No significant difference was observable with and without the HiTEC 3000 additive (Blend 8 vs. 7). Within the accuracy of the methods used, the effect of the HiTEC 3000 additive blended alone in the base fuel or when in oxygenate blends was comparable in all instances with the changes observed with no HiTEC 3000 additive present. The changes observed even with Blends 7 and 8 are not deemed sufficient to preclude use of any elastomer with the HiTEC 3000 additive. Complete test results are reported in Attachment 3-18.

(b) Plastics

The plastics tested were:

HDPE (High Density Polyethylene)
PETG (Polyethylene Terephthalate)
Delrin (Acetal Homopolymer)
Nylon 6/6 (Nylon)
Nylon 11 (Nylaflow LM)

Additional information on these materials is given in the appendix to Attachment 3-18, Materials, Table II.

Test methods used in the evaluation were:

ASTM D 543, Resistance of Plastics to Chemical Reagents. This test provides information on changes in weight, dimensions, appearance and strength of specimens after exposure to liquids.

ASTM D 638, Tensile Properties of Plastics. This test gives tensile strength of reinforced and unreinforced plastics under defined conditions of pretreatment, temperature, humidity and testing machine speed.

ASTM D 790, Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. This test determines flexural properties of rigid and semi-rigid materials.

The eight fresh fuel blends listed on page 7, Appendix 3, were evaluated for compatibility with five plastic materials in a long-term (12-week) static test simulating occasional automobile use with infrequent refills of the gas tank under relatively warm weather conditions. The test was conducted at the high ambient temperature of 110°F to maximize possible breakdown of, and interaction between, additives and fuel components to develop possible agents which might attack the plastics. The test purpose was to compare the effects on the plastics of the base fuel with and without the HiTEC 3000 additive and similarly to compare the effects of three oxygenate blends with and without the HiTEC 3000 additive. No significant deterioration of any plastic was found. Indeed, in general the change in properties was due to the base fuel. Nor were there significant differences when comparing effects with the base fuel alone and with additives present or when comparing the oxygenate blends alone with those containing the HiTEC 3000 additive.

The evaluation of compatibility was made by determining changes in several properties at 2, 4, and 12 weeks from those measured initially. The properties measured are typically used to determine the usefulness of plastics in applications such as fuel systems. These properties included appearance, strength, volume swell, tensile strength and flexural properties as measured by standard (ASTM) procedures. The results are similar to those reported by others, for example "Clean Air Act Waiver Application, Vol. 3, E.I. DuPont, July 11, 1984.

There was some effect on several plastics when exposed to the methanol/propanol blend (Blend 7), but no significant difference was observable with the HiTEC 3000 additive present (Blend 8). Within the accuracy of the methods used, the effect of the HiTEC 3000 additive blended alone in the base fuel or when in oxygenate blends was comparable in all instances with the changes observed with no HiTEC 3000 additive present. The changes observed even with Blends 7 and 8 are not deemed sufficient to preclude use of these plastics with the HiTEC 3000 additive. Complete test results are reported in Attachment 3-18.

4. <u>Storage Stability Tests of Fuels</u>

ASTM D 439 and D 4814 list a series of standard tests along with recommended specifications that are commonly used to define gasoline quality. Gasolines meeting these specifications are suitable for typical vehicle operations. While ASTM D 439 and D 4814 are not in themselves legally binding, they often are referenced in State documents covering the quality of petroleum products purchased by State governments. The standards for the individual tests may vary somewhat depending on geographical, seasonal and other operational variables for the particular area. Oil companies also use these tests in setting specifications for the gasolines that they market in various areas.

Storage stability characteristics of gasolines are very important to the refiner, the filling station operator and the motoring public. If gummy residues are formed during storage, due to oxidation or other reactions, they can foul critical parts of the vehicle system such as carburetors, injectors, filters and control sensing elements.

To determine the stability of gasoline, Ethyl conducted the following tests:

ASTM D 381	Existent Gum in Fuels By Jet Evaporation.
ASTM D 525	Oxidation Stability of Gasoline (Induction Period Method).
ASTM D 873	Oxidation Stability of Aviation Fuels (Potential Residue Method).
ASTM D 4625	Distillate Fuel Storage Stability at 43°C (110°F).

The first three test procedures are routinely used in gasoline testing. They are quality control tests designed to evaluate gasoline rapidly, under accelerated conditions. There is no long-term storage test specifically designed for gasoline. Therefore, the procedures in ASTM D 4625, which are designed to analyze distillate fuels, were modified slightly so that gasoline, being more volatile than distillate fuels, could be safely handled. In ASTM D 4625, fuels are tested at 110°F for 12 weeks. Industry studies indicate that storage under laboratory conditions for one week at 110°F is equivalent to storage for four weeks under ambient conditions. Thus, at the end of the test period, the results should show the quality of the fuel after storage for about one year.

The HiTEC 3000 additive is sensitive to sunlight. The organo-manganese compound can oxidize in the presence of light to form inorganic oxides of manganese. These oxides do not have the ability to raise octane quality like the original material. Further, the manganese oxides can precipitate from gasoline as small black flecks. Therefore, care was taken during preparation and testing of the fuels so that exposure to both sunlight and normal indoor lighting was minimized.

Today's gasolines are not exposed to sunlight during their distribution and sale. Therefore, the HiTEC 3000 additive's sensitivity to sunlight poses no problem.

Final test results from ASTM methods D 381, D 525, D 873 and D 4625 are reported in Attachment 3-19. The addition of the HiTEC 3000 additive to the four different fuel blends had no significant effect on (1) the existent gum content, (2) the induction period, which is one accelerated measure of the tendency of a gasoline to form gum in storage, (3) potential gum, another accelerated test used by some oil companies to indicate the tendency of a fuel to form gum in storage, and (4) long-term storage.

Test results on all fuels meet specifications listed in ASTM D 439 and D 4814. There were no significant effects of the HiTEC 3000 additive on the various gasoline blends. Therefore, the HiTEC 3000 additive should not have any effect on the stability of gasolines sold in the U.S.

These fuel stability test results are further confirmed by the fact that the HiTEC 3000 additive has not caused fuel stability problems in Canada in over eleven years of constant use, at concentrations ranging up to twice as high as that requested in this waiver application.

C. EVAPORATIVE EMISSIONS

The HiTEC 3000 additive, methylcyclopentadienyl manganese tricarbonyl, has a vapor pressure of 0.05 mm mercury at 20°C, with a boiling point of 232°C. It is completely miscible in gasoline, and does not form azeotropic mixtures with gasoline or with any of the individual chemical compounds that make up gasolines.

The maximum concentration of the HiTEC 3000 additive covered under this waiver is 0.03125 grams of manganese per gallon of gasoline. At that concentration, the HiTEC 3000 additive represents about 0.005% by weight of the gasoline blend. Because of the extremely low concentration of the HiTEC 3000 additive in gasoline, and the low volatility of the additive, it will have no effect on evaporative emissions from vehicles.

Notwithstanding these considerations, Ethyl used the 1978 SHED test procedure to measure the evaporative emissions on 8 of the test fleet vehicles after 50,000 miles of vehicle operation. The results are reported in Attachment 3-20. Three of the four vehicle pairs showed less evaporative emissions with fuel containing the HiTEC 3000 additive than with the clear test fuel. The average evaporative emissions from the four vehicle pairs was less when HiTEC 3000 was present in the fuel. These test results thus confirm that HiTEC 3000 has no adverse effect on evaporative emissions.

D. DRIVEABILITY

The HiTEC 3000 additive is not expected to affect the driveability of automobiles.[8/] Fuel additives have little, if any, effect on driveability, with the exception of detergents which can reduce

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8/ In the prior waiver application for the HiTEC 3000 additive, EPA did not express any concern that the HiTEC 3000 additive would affect the driveability of automobiles.

degradation of driveability. Gasoline blended with alcohols can affect driveability because of the alcohol's effect on the volatility of the gasoline blend. The HiTEC 3000 additive should not affect driveability because it does not change the volatility, density or handling characteristics of a fuel.9/ 10/

Nevertheless, Ethyl designed the waiver application test protocol to allow for the consideration of driveability issues. The test protocol required vehicle drivers to maintain a log of significant events that occurred during each shift of vehicle operation in the test program. The drivers recorded comments about any unusual conditions experienced with the vehicle -- e.g., difficult starting, stalling, or other mechanical problems encountered by the driver -- which might require non-routine vehicle maintenance, and which might have a bearing on the vehicle's exhaust emissions. If several drivers reported similar problems with a specific car, then the "on site" manager would confirm these observations. When this occurred, the car was returned to the dealer for diagnosis and repair. If the repairs involved emission control components, the car was tested on the FTP prior to continuing mileage accumulation.

Representative samples of the vehicle log from ECS and ATL are attached to this Appendix as Attachments 3-21 and 3-22. A review of the vehicle logs shows that the HiTEC 3000 additive had no effect on the driveability of the test vehicles.11/

E. PARTICULATE EMISSIONS

Ethyl determined the amount of manganese emitted from fleet test cars using fuel containing the HiTEC 3000 additive in order to estimate airborne manganese concentrations.

After 75,000 miles had been accumulated on the test vehicles, airborne particulates were measured from three car models using the EPA particulate sampling techniques per CFR 86.110-82, 86.111-82 and 86.112-82. This tunnel technique is used primarily for diesel particulate studies. Before the fleet cars were tested, the tunnel and sampling system were cleaned and preconditioned using exhaust from an unleaded test fleet vehicle. Particulate emissions were measured for both clear Howell EEE and Howell EEE containing 0.03125 grams of manganese as HiTEC 3000 in three model groups: Groups "E", "G" and "T".

9/ Appendix 1, Attachment 1-2.

10/ Appendix 3, page 14, "Evaporative Emissions."

11/ Because the vehicle logs are voluminous (one log per vehicle having entries for each shift of vehicle operation), Ethyl has not submitted the vehicle logs in their entirety. They can be made available to EPA upon request.

Particulate filters for each bag were analyzed for manganese content at Ethyl's Baton Rouge Research Center.

Particulate emissions for the 9 cars fueled with clear Howell EEE averaged 0.007 grams per mile, while the 9 cars using Howell EEE containing HiTEC 3000 averaged 0.004 grams per mile. Average manganese emissions for the 9 cars using HiTEC 3000 was less than 5.0 micrograms per mile, or about 0.40 percent of the manganese input to the engine in the fuel.

Data for the 18 cars are shown in Attachment 3-23.

Attachment 3-1

SUMMARY OF OXYGEN SENSOR EVALUATION[1/]

	Hydrocarbons		Carbon Monoxide		Nitrogen Oxide	
Model	Mean Diff.[2/]	Stat. Sign.[3/]	Mean Diff.[2/]	Stat. Sign.[3/]	Mean Diff.[2/]	Stat. Sign.[3/]
C	0.009	No	0.165	No	-0.009	No
D	-0.002	No	0.141	No	-0.040	No
E	-0.003	No	-0.220	No	-0.030	No
F	-0.014	No	-0.513	No	-0.109	No
G	-0.022	No	-1.027	No	-0.173	No
H	0.053	No	0.157	No	-0.027	No
I	-0.009	No	-0.086	No	-0.011	No
T	0.006	No	0.039	No	-0.043	No

1/ "Test bed" vehicle tailpipe emissions with sensors run on HiTEC 3000 - sensors run on Howell EEE.

2/ Mean difference in gm/mile after sensors used for 50,000 miles.

3/ Statistical significance at the 95% confidence level.

Attachment 3-2

OXYGEN SENSOR EVALUATION – MODEL GROUP C

Tailpipe Emission Data

	Sensors Tested in Car C4		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car C1	0.165	1.868	0.386
C5	0.146	2.213	0.406
C4	0.157	2.533	0.498
Average	0.156	2.205	0.430
Std. Dev.	0.010	0.333	0.060
HiTEC 3000 Sensor From			
Car C2	0.151	2.113	0.419
C3	0.162	2.534	0.362
C6	0.181	2.463	0.483
Average	0.165	2.370	0.421
Std. Dev.	0.015	0.225	0.061
HiTEC 3000 Minus Clear Fuel			
Mean Difference	0.009	0.165	-0.009
95% Confidence Interval			
Upper	0.037	0.809	0.128
Lower	-0.020	-0.479	-0.145
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

Attachment 3-3

OXYGEN SENSOR EVALUATION - MODEL GROUP D

Tailpipe Emission Data

	Sensors Tested in Car D2		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car D1	0.598	4.086	0.454
D2	0.584	3.520	0.565
D3	0.649	4.546	0.449
Average	0.610	4.051	0.489
Std. Dev.	0.034	0.514	0.066
HiTEC 3000 Sensor From			
Car D4	0.591	4.179	0.419
D5	0.605	4.122	0.467
D6	0.629	4.275	0.461
Average	0.608	4.192	0.449
Std. Dev.	0.019	0.077	0.026
HiTEC 3000 Minus Clear Fuel			
Mean Difference	-0.002	0.141	-0.040
95% Confidence Interval			
Upper	0.061	0.974	0.073
Lower	-0.065	-0.692	-0.153
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

Attachment 3-4

OXYGEN SENSOR EVALUATION - MODEL GROUP E

Tailpipe Emission Data

	Sensors Tested in Car E4		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car E2	0.182	5.634	0.526
E3	0.183	5.625	0.505
E4	0.169	5.270	0.413
Average	0.178	5.510	0.481
Std. Dev.	0.008	0.208	0.060
HiTEC 3000 Sensor From			
Car E1	0.172	5.367	0.473
E5	0.161	5.019	0.485
E6	0.193	5.484	0.396
Average	0.175	5.290	0.451
Std. Dev.	0.016	0.242	0.048
HiTEC 3000 Minus Clear Fuel			
Mean Difference	-0.003	-0.220	-0.030
95% Confidence Interval			
Upper	0.026	0.291	0.094
Lower	-0.032	-0.731	-0.154
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

Attachment 3-5

OXYGEN SENSOR EVALUATION - MODEL GROUP F

Tailpipe Emission Data

	Sensors Tested in Car F6		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car F6	0.689	2.889	0.870
F4	0.825	2.928	0.799
F5	0.705	2.304	0.891
Average	0.740	2.707	0.853
Std. Dev.	0.074	0.350	0.891
HiTEC 3000 Sensor From			
Car F1	0.784	2.439	0.717
F2	0.790	2.242	0.729
F3	0.603	1.900	0.788
Average	0.726	2.194	0.745
Std. Dev.	0.106	0.273	0.038
HiTEC 3000 Minus Clear Fuel			
Mean Difference	-0.014	-0.513	-0.109
95% Confidence Interval			
Upper	0.194	0.197	-0.010
Lower	-0.222	-1.224	-0.207
"t" test 95% Conf. Int.	N.S.	N.S.	Yes

Attachment 3–6

OXYGEN SENSOR EVALUATION – MODEL GROUP G

Tailpipe Emission Data

	Sensors Tested in Car G1		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car G1	0.137	3.234	0.395
G2	0.185	2.939	0.830
G4	0.156	1.979	0.351
Average	0.159	2.717	0.525
Std. Dev.	0.024	0.656	0.265
HiTEC 3000 Sensor From			
Car G3	0.137	1.529	0.345
G5	0.142	1.910	0.363
G6	0.132	1.633	0.348
Average	0.137	1.691	0.352
Std. Dev.	0.005	0.197	0.010
HiTEC 3000 Minus Clear Fuel			
Mean Difference	–0.022	–1.027	–0.173
95% Confidence Interval			
Upper	0.017	0.071	0.251
Lower	–0.062	–2.125	–0.598
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

Attachment 3-7

OXYGEN SENSOR EVALUATION - MODEL GROUP H

Tailpipe Emission Data

	Sensors Tested in Car H1		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car H2	0.300	4.695	0.424
H5	0.282	3.319	0.405
H1	0.190	3.466	0.451
Average	0.257	3.827	0.427
Std. Dev.	0.059	0.756	0.023
HiTEC 3000 Sensor From			
Car H4	0.324	4.465	0.434
H6	0.296	3.399	0.357
H3	0.311	4.088	0.407
Average	0.310	3.984	0.399
Std. Dev.	0.014	0.541	0.039
HiTEC 3000 Minus Clear Fuel			
Mean Difference	0.053	0.157	-0.027
95% Confidence Interval			
Upper	0.150	1.646	0.045
Lower	-0.044	-1.332	-0.100
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

Attachment 3-8

OXYGEN SENSOR EVALUATION – MODEL GROUP I

Tailpipe Emission Data

	Sensors Tested in Car I3		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car I1	0.159	2.464	0.574
I5	0.208	3.476	0.794
I3	0.146	2.311	0.567
Average	0.171	2.750	0.645
Std. Dev.	0.033	0.633	0.129
HiTEC 3000 Sensor From			
Car I2	0.169	3.044	0.642
I6	0.155	2.285	0.626
I4*	----	----	----
Average	0.162	2.665	0.634
Std. Dev.	0.010	0.537	0.011
HiTEC 3000 Minus Clear Fuel			
Mean Difference	-0.009	-0.086	-0.011
95% Confidence Interval			
Upper	0.070	1.665	0.296
Lower	-0.088	-1.836	-0.318
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

* Oxygen sensor damaged during removal

Attachment 3-9

OXYGEN SENSOR EVALUATION - MODEL GROUP T

Tailpipe Emission Data

	Sensors Tested in Car T6		
	HC gm/Mi.	CO gm/Mi.	NOx gm/Mi.
Clear Fuel Sensor From			
Car T6	0.379	6.132	0.863
T2	0.352	5.338	0.824
T3	0.423	6.189	0.773
Average	0.385	5.886	0.820
Std. Dev.	0.036	0.476	0.045
HiTEC 3000 Sensor From			
Car T1	0.437	6.246	0.710
T4	0.358	5.981	0.817
T5	0.376	5.550	0.803
Average	0.390	5.926	0.777
Std. Dev.	0.041	0.351	0.058
HiTEC 3000 Minus Clear Fuel			
Mean Difference	0.006	0.039	-0.043
95% Confidence Interval			
Upper	0.093	0.987	0.075
Lower	-0.082	-0.908	-0.161
"t" test 95% Conf. Int.	N.S.	N.S.	N.S.

Attachment 3-10

50,000 MILE SENSORS VS NEW SENSORS

Compared in "Test-Bed" Vehicles

	50,000 Mile Sensors		
	Howell EEE Clear	Howell EEE H3000	New Sensors
	Hydrocarbons, gm/Mile		
Car Model Group*			
C	0.156	0.165	0.170
E	0.178	0.175	0.354
G	0.159	0.137	0.157
H	0.257	0.310	0.354
I	0.171	0.162	0.166
T	0.385	0.390	0.423
Average	0.218	0.223	0.271
	Carbon Monoxide, gm/Mile		
Car Model Group*			
C	2.205	2.370	2.382
E	5.510	5.290	5.885
G	2.717	1.691	2.292
H	3.827	3.984	4.029
I	2.750	2.665	2.615
T	5.886	5.926	5.246
Average	3.816	3.654	3.742
	Nitrogen Oxides, gm/Mile		
Car Model Group*			
C	0.430	0.421	0.429
E	0.481	0.451	0.544
G	0.525	0.352	0.404
H	0.427	0.399	0.319
I	0.645	0.634	0.679
T	0.820	0.777	0.806
Average	0.555	0.506	0.530

* New oxygen sensors were not tested in Car Model Groups D and F. The testing program with new oxygen sensors was started after 50,000 mile oxygen sensor testing was completed on Car Model Groups D and F, and the cars were already accumulating additional mileage.

Attachment 3-11

CATALYTIC CONVERTER PERFORMANCE

Percentage Point Loss in Efficiency

		Hydrocarbons Efficiency Loss		Carbon Monoxide Efficiency Loss		Nitrogen Oxide Efficiency Loss	
Car Model	Fuel	@50,000 Miles	@75,000 Miles	@50,000 Miles	@75,000 Miles	@50,000 Miles	@75,000 Miles
C	HiTEC 3000	2.3	4.9	9.0	17.3	6.5	6.6
	Clear	2.8	5.9	13.1	16.1	11.6	12.0
D	HiTEC 3000	11.9	12.4	22.3	27.4	-0.1	-0.5
	Clear	11	15.1	13.9	25.6	-2.5	-3.0
E	HiTEC 3000	5.7	7.1	25.1	28.0	12.5	10.9
	Clear	7.7	8.7	29.8	34.5	15.6	15.2
G	HiTEC 3000	5.5	6.2	17.0	22.9	6.9	7.2
	Clear	6.1	8.0	18.4	21.2	9.6	11.0
H	HiTEC 3000	8.1	9.9	19.1	20.5	0.9	-6.8
	Clear	7.1	8.9	15.9	20.7	6.0	7.6
I	HiTEC 3000	3.7	2.4	7.7	8.3	5.1	4.1
	Clear	2.8	1.9	7.4	5.7	11.5	11.8
T	HiTEC 3000	6.5	5.9	22.6	20.5	3.6	0.1
	Clear	8.2	7.5	25.7	23.8	6.4	2.5
Fleet	**HiTEC 3000**	**6.2**	**7.0**	**17.5**	**20.7**	**5.1**	**3.1**
	Clear	**6.5**	**8.0**	**17.7**	**21.1**	**8.3**	**8.2**

Note – All comparisons are made to conversion efficiency calculations at 1,000 miles.

Attachment 3-12

CATALYST CONVERSION EFFICIENCY

Hydrocarbons

Car Model	Fuel	1,000 Miles	50,000 Miles	75,000 Miles
C	HiTEC 3000	90.9	88.6	86.0
	Clear	91.4	88.6	85.5
D	HiTEC 3000	88.3	76.4	75.9
	Clear	88.6	77.6	73.5
E	HiTEC 3000	94.4	88.7	87.3
	Clear	94.6	86.9	85.9
G	HiTEC 3000	92.0	86.5	85.8
	Clear	93.4	87.3	85.4
H	HiTEC 3000	94.3	86.2	84.4
	Clear	94.1	87.0	85.2
I	HiTEC 3000	93.7	90.0	91.3
	Clear	93.2	90.4	91.3
T	HiTEC 3000	91.1	84.6	85.2
	Clear	91.8	83.6	84.3
Fleet	**HiTEC 3000**	**92.1**	**85.9**	**85.1**
	Clear	**92.4**	**85.9**	**84.4**

Note – All models run on clear fuel to 1,000 miles.

Attachment 3-13

CATALYST CONVERSION EFFICIENCY

Carbon Monoxide

Car Model	Fuel	1,000 Miles	50,000 Miles	75,000 Miles
C	HiTEC 3000	80.3	71.3	63.0
	Clear	82.6	69.5	66.5
D	HiTEC 3000	89.0	66.7	61.6
	Clear	83.6	69.7	58.0
E	HiTEC 3000	78.0	52.9	50.0
	Clear	80.3	50.5	45.8
G	HiTEC 3000	89.3	72.3	66.4
	Clear	88.6	70.2	67.4
H	HiTEC 3000	88.9	69.8	68.4
	Clear	88.5	72.6	67.8
I	HiTEC 3000	87.5	79.8	79.2
	Clear	83.6	76.2	77.9
T	HiTEC 3000	85.9	63.3	65.4
	Clear	86.9	61.2	63.1
Fleet	**HiTEC 3000**	**85.6**	**68.0**	**64.9**
	Clear	**84.9**	**67.1**	**63.8**

Note – All models run on clear fuel to 1,000 miles.

Attachment 3-14

CATALYST CONVERSION EFFICIENCY

Nitrogen Oxides

Car Model	Fuel	1,000 Miles	50,000 Miles	75,000 Miles
C	HiTEC 3000	96.0	89.5	89.4
	Clear	95.9	84.3	83.9
D	HiTEC 3000	74.9	75.0	75.4
	Clear	74.2	76.7	77.2
E	HiTEC 3000	91.6	79.1	80.7
	Clear	92.8	77.2	77.6
G	HiTEC 3000	84.2	77.3	77.0
	Clear	86.9	77.3	75.9
H	HiTEC 3000	67.3	66.4	74.1
	Clear	73.3	67.3	65.7
I	HiTEC 3000	85.8	80.7	81.7
	Clear	87.5	76.0	75.7
T	HiTEC 3000	84.4	80.8	84.3
	Clear	83.4	77.0	80.9
Fleet	**HiTEC 3000**	**83.5**	**78.4**	**80.4**
	Clear	**84.9**	**76.5**	**76.7**

Note – All models run on clear fuel to 1,000 miles.

Attachment 3–15

EXHAUST BACK PRESSURE SUMMARY
Ethyl Fleet Cars *

Howell EEE Fuel Car Number	B.P.**	Howell EEE + HiTEC 3000 Car Number	B.P.**
C1	7.3	C2	7.4
C4	6.9	C3	7.5
C5	7.1	C6	7.5
Average	7.1	Average	7.5
D1	16.0	D4	15.9
D2	15.7	D5	15.5
D3	15.8	D6	15.2
Average	15.8	Average	15.5
E2	7.6	E1	6.9
E3	6.7	E5	6.8
E4	7.4	E6	7.4
Average	7.2	Average	7.0
G1	8.5	G3	9.2
G2	10.1	G5	9.8
G4	9.0	G6	9.0
Average	9.2	Average	9.3
H1	10.5	H3	10.9
H2	10.9	H4	10.8
H5	10.8	H6	10.8
Average	10.7	Average	10.8
I1	17.0	I2	16.9
I3	17.0	I4	17.3
I5	17.1	I6	17.6
Average	17.0	Average	17.3
T2	16.5	T1	16.6
T3	16.7	T4	16.6
T6	16.6	T5	16.8
Average	16.6	Average	16.7

* Measured at 4500 rpm and wide open throttle, after the fleet cars had accumulated 75,000 miles.

** Back pressure in inches of mercury.

Attachment 3-16

HIGH SPEED TEST SCHEDULE

ATL Test Track

A. Schedule for first 25,000 miles

Mile	
0.0	Leave start position at 15-20 mph. Accelerate to 35 mph.
0.3	Reduce speed to 15 mph (brake retard).
0.4	Stop. Accelerate to 55 mph.
1.9	Slow to 45 mph. Maintain.
3.3	Accelerate to 65 mph. Maintain.
6.0	Reduce speed to 35 mph.
6.3	Reduce speed to 15 mph (brake retard).
6.4	Stop. Accelerate to 55 mph, etc.

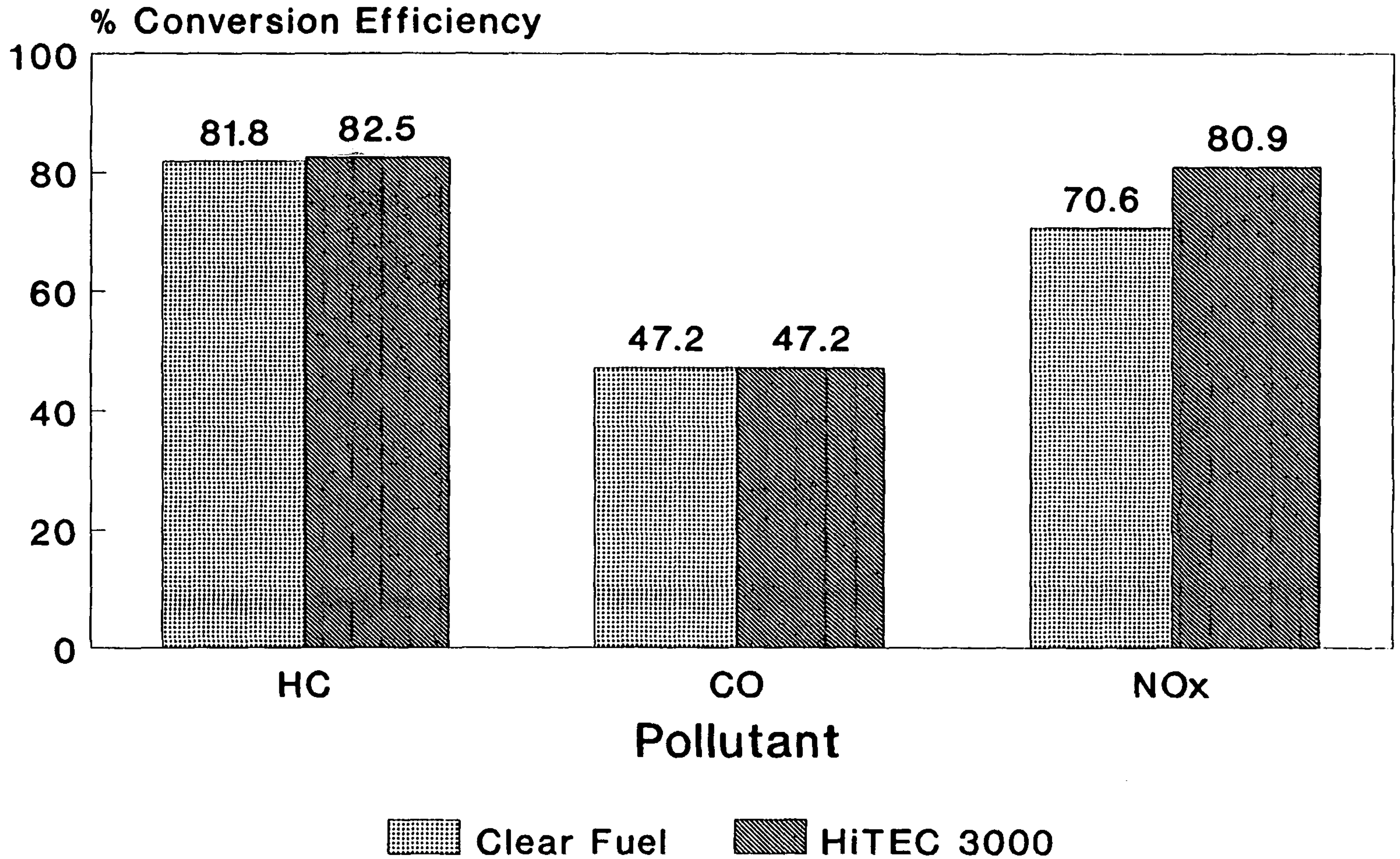
Speed, mph	15	35	45	55	65
Distance, miles	0.1	0.3	1.4	1.5	2.7
Percent (Approx.)	2	5	23	25	45

B. Schedule for additional 10,000 miles.

The same schedule was followed except the speed of the 65 mph portion was increased to 80 mph.

EXTENDED DURABILITY OF EMISSION SYSTEMS

100,000 Mile Test of 4 Corsicas



Attachment 3-17

Attachment 3-18

LABORATORY STUDY OF THE COMPATIBILITY OF A VARIETY OF MATERIALS WITH SEVERAL FUEL BLENDS CONTAINING ADDITIVES

FUEL STABILITY

Test	ASTM Test Method	Howell EEE Clear	Howell EEE H3000*	Howell EEE + 10% Ethanol Clear	Howell EEE + 10% Ethanol H3000*	Howell EEE + 15% MTBE Clear	Howell EEE + 15% MTBE H3000*	Howell EEE + 4.5% MeOH+4.5% IPA Clear	Howell EEE + 4.5% MeOH+4.5% IPA H3000*
Existent Gums mg/100 mls	D 381	0.5	0.5	1.3	1.3	0.6	0.7	1.4	1.5
Induction Period Minutes	D 525	1440+	1440+	1440+	1440+	1440+	1440+	1440+	1440+
Potential Residue									
5 Hour Aging	D 873								
Gums, mg/100 ml		2.1	2.4	5.5	4.7	1.0	1.0	5.2	4.9
Precipitate, mg/100 ml		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long-Term Storage									
Stability	D 4625								
Gums, mg/100 ml									
4 weeks		1.5	1.8	2.8	2.9	2.0	1.2	2.8	2.9
8 weeks		2.1	2.1	3.5	3.8	2.3	2.4	4.2	4.2
12 weeks		1.2	1.4	3.1	1.5	1.4	1.5	3.0	3.1

* 0.03125 gm Mn/USG as HiTEC 3000

Attachment 3-20

EVAPORATIVE EMISSIONS

Howell EEE Fuel		Howell EEE + HiTEC 3000*	
Car Number	Total HC Emitted, Grams	Car Number	Total HC Emitted, Grams
E2	0.739	E1	0.460
F5	0.430	F2	0.825
T2	0.852	T1	0.344
C1	0.419	C2	0.417
Average	0.610	Average	0.512

* 0.03125 grams manganese/U.S. Gallon

Attachment 3-21

PM Shift

TRI-CITY TOWING
Phone # 471-2666

E.C.S. Phone #591-4310

CAR: B-8

DRIVERS DAILY LOG

Date: January 24, 1990 Driver: George Greul

Fuel Pumped From: EEE Amount: 4.2

Car Make: 1988 Buick Car Model: Century 2.8

Transmission: Automatic

HAVE YOU CHECKED YOUR:

Engine Oil OK Transmission Fluid OK Tires OK

Power Steering Fluid OK Wiper Fluid OK Interior OK

Radiator OK Comments: 2 Taps

Start		Stops		Finish	
Odo.	Time	Time Out	Time In	Odo.	Time
70630	1:28	1:30	5:50	70750	5:50
				120	

Attachment 3-22

ATL VEH -17

B-17

Project Record

Computation Book

Do not remove

from vehicle.

Project Record No.

BD-1025

4-25-89 DE YORK 7013 7001
B-17 START 39203 FINISH 39435
LABOR 8.8 TRACK 7.5
NO NEW INCIDENTS RAN 232 MILES

4/25/89 D. SUSAN 7013 7001
B-17 39435 - 39661
LABOR 8.7 TRACK 7.8
NO NEW INCIDENTS RAN 226

4-26-89 M. D. 7013 7001
B-17 39661 — 39894
Labor 8.8 Track 7:30
No New Incidents RAN 233 miles
[illegible] 37001
B-17 ODM 39994 STAR-
LABOR - TRACK -
NO PROBLEMS RAN -
4/26/89 RADCKEY 70137001
B-17 ODM START 39894 STOP 39999
LABOR 4.0 TRACK 4.0
NO PROBLES RAN 105 MILE

4/28/89 TEST #1 OK
5/01/89 TEST #2 OK
5/01/89 VEHICLE BACK TO BAPG ODO 40053

5-2-89 B. Szuela 70137001
B-17 St 40053 Fin 40277
Lab 8.8 Track 7.8
[illegible]

5/3/89 D. Jaskowi 7013 7001
B-17 St 40277 - Fin 40507
L 8.9 Tr 7.30 Ran 230 miles
No New Incidents
5-4-89 [illegible] 70137001
B-17 40507 — 40682
No New Incidents

Attachment 3-23

AIRBORNE PARTICULATE EMISSIONS

1975 FTP-CVS Procedure

Howell EEE		Howell EEE with HiTEC 3000*			
Car Number	gm/Mile Total**	Car Number	gm/Mile Total**	u gm Mn/Mile	Percent Manganese Emitted
G1	0.003	G3	0.004	4.1	0.38
G2	0.008	G5	0.005	5.1	0.40
G4	0.014	G6	0.004	4.4	0.34
E2	0.005	E1	0.003	7.3	0.64
E3	0.007	E5	0.002	3.1	0.28
E4	0.007	E6	0.004	7.2	0.64
T2	0.010	T1	0.004	3.1	0.18
T3	0.006	T4	0.004	3.2	0.20
T6	0.004	T5	0.005	7.3	0.47
Average	0.007	Average	0.004	5.0	0.39

* 0.03125 gm manganese per gallon as HiTEC 3000

** Total Airborne Particulates

CORTEST
LABORATORIES

LABORATORY STUDY OF THE
COMPATIBILITY OF A VARIETY
OF MATERIALS WITH SEVERAL FUEL
BLENDS CONTAINING ADDITIVES

Prepared for:
ETHYL CORPORATION
PROCESS DEVELOPMENT CENTER
ATTENTION: MR. C. R. BERGEN

AND

ETHYL CORPORATION
PETROLEUM ADDITIVES DIVISION
ATTENTION: MR. A.M. BURNS

Prepared by:
WILLIAM G. ASHBAUGH
SENIOR CONSULTANT, P.E.
ENGINEERING SERVICES & RELIABILITY
CORTEST LABORATORIES, INC.

DATE PREPARED: March 27, 1990
CORTEST NO. : L93712A

11115 Mills Rd., Suite 102 Cypress, Texas 77429 (713) 890-7575

INDEX

I - INTRODUCTION

At the request of the Ethyl Corporation, Cortest Laboratories has conducted a series of laboratory environmental exposures of various materials to a variety of gasoline fuel blends. The materials evaluated represent those metals, plastics and elastomers commonly used in and around the fuel systems of automobiles. Various gasoline blends were supplied with and with out an Ethyl Petroleum Additives Division (AD) proposed additive. Cortest Laboratories ran the tests blind, that is they were not given the composition of the eight fuel mixtures tested. All tests were performed in accordance with ASTM standards and approved laboratory practice.

II - SUMMARY

The fuel compatibility tests consisted of exposure specimens of seven different metals, five plastics, and five elastomers to the eight fuel blends for twelve weeks. The results of the tests clearly demonstrate that no significant degradation effects differences were noted between the four test pairs of fuel blends.

III - TEST PROCEDURES

Eight fuel blends were tested. These consisted of four blends each with and with-out the Ethyl AD additive. The test procedure thus is a direct comparison between four pairs of fuel blends. The test exposure lasted for 12 weeks with one set of specimens being evaluated after 2 weeks, a second set after 4 weeks and the final set after 12 weeks. The metal samples were not evaluated at the 2 week internal.

The fuel samples were held at 110 F ± 2 F and 75 percent of the fuel was replaced with fresh fuel at the 2 and 4 week intervals. The fuel blends were stored in sealed 5 gallon containers which were placed in a water/glycol bath for temperature control.

The Tables I and II in the Appendix list the materials tested and the ASTM tests used to evaluate their properties before and after test exposures. The flexural modulus tests were not run on the plastics as requested because all of the materials were too flexible to measure using this technique. The only variation from the standard procedure occurred in the shape of the metal coupons used in NACE TM01-72. This method called for a cylindrical coupon threaded on one end. In order to expedite the test program flat metal strips were used of the same surface area as the cylinder.

In order to produce a measure of consistency in test results the elastomer and the plastic coupons upon removal from the fuel were laid out on paper towels, at room temperature (72 F), for 1 hour. They were then sealed in polyethylene bags until the moment they were to be tested.

Since this test program is one of direct comparison of materials performance in various fuel blends only duplicate test coupons were used. The materials were all tested in air and the data used to obtain percent change in the property tested. The duplicate specimen data was averaged and the data point plotted in the attached charts. All the test data is printed out and is presented in Section 3 of the Appendix, this information is also on the computer diskette enclosed with the report to Mr. Bergen. The data is in the Lotus 1-2-3 format. All the 12 week raw data was reviewed for abnormal results caused by variations in sample quality. When a data point is out of control it is not used in the averaging process. The data points not used are indicated by a (*) at the number.

The data file contains the two, four and twelve week data. The summary bar graphs are based only on the twelve week average data which is the definitive information. The two and four week data points were taken primarily to observe trends.

IV DATA REVIEW

An overall review of the data has been conducted to determine if there are any noticeable differences between the four pairs of blends. It is apparent that the blend pairs are 1 and 2, 3 and 4, 5 and 6, and 7 and 8.

Comparing the properties of the plastics and elastomers as shown in each pair blends we find no significant differences which would indicate the presence of a harmful additive. The bar charts attached are used to summarize the large amount of data. While there are differences between blends, considering the order of magnitude of the difference, the changes are small.

The evaluations of the metals are shown in separate tables attached to this report. Neither the static twelve week test or the NACE anti-rust test developed any indications of unusual effects on the metals by an additive.

Prepared by: William G. Ashbaugh Date: 3-29-90
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Reviewed by: A Coates Date: 3-29-90
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Engineering Services & Reliability Group
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WGA-10/L93712A.R

12 Weeks Data & Graphs

1. Metals static tests
2. Metals NACE TM01-72
3. Elastomers
4. Plastics

METALS

TABLE I

METALS STATIC STORAGE TWELVE WEEK EXPOSURE RESULTS
(WEIGHT LOSS PER SPECIMEN IN GRAMS PER CM2)

FUEL BLENDS	STEEL 1010	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.197)	ALUMINUM 329	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=46.378)	ZINC ZIMAK 3	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=57.142)
1	0.0072	0.0001281207	0.0016	0.00003450	0.0025	0.00004375
2	0.0083	0.0001476947	0.0001	0.00000216	0.0039	0.00006825
3	0.0059	0.0001049878	0.0002	0.00000431	0.0039	0.00006825
4	0.0084	0.0001494742	0.0001	0.00000216	0.0049	0.00008575
5	0.0079	0.0001405769	0.0007	0.00001509	0.0033	0.00005775
6	0.0087	0.0001548125	0.0007	0.00001509	0.0004	0.00000700
7	0.0092	0.0001637098	0.0019	0.00004097	0.0039	0.00006825
8	0.0088	0.0001565920	0.0022	0.00004744	0.0032	0.00005600

...EL ...NDS	COPPER 110	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.935)	ADM. BRASS 443	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.834)	CADIUM PLATE ON CADIUM	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=59.420)	TERNE COATING ON STEEL	CHANGE IN WEIGHT PER UNIT AREA (AREA Cm2=56.109)
1	0.0300	0.00052692	0.0112	0.00019707	0.0011	0.00001851	0.0091	0.00016218
2	0.0331	0.00058136	0.0142	0.00024985	0.0006	0.00001010	0.0059	0.00010515
3	0.0208	0.00036533	0.0327	0.00057536	0.0079	0.00013295	0.0058	0.00010337
4	0.0050	0.00008782	0.0267	0.00046979	0.0043	0.00007237	0.0037	0.00006594
5	0.0176	0.00030912	0.0102	0.00017947	0.0033	0.00005554	0.0078	0.00013902
6	0.0144	0.00025292	0.0125	0.00021994	0.0011	0.00001851	0.0092	0.00016397
7	0.0339	0.00059542	0.0248	0.00043636	0.0004	0.00000673	0.0147	0.00026199
8	0.0473	0.00083060	0.0222	0.00039061	0.0047	0.00007910	0.0097	0.00017288

TABLE II

NACE TM01-72 ANTI RUST TEST (12 WEEK DATA)
(APPEARANCE)

FUEL BLEND	METAL	COMMENTS
1	ALUMINUM	No discolor, stains, corrosion, pits or rust build up.
2	ALLOY	No discolor, stains, corrosion spot (pits, rust) build up.
3		No discolor, stains, corrosion spot (pits, rust) build up.
4	SAE 329	No discolor, stains, corrosion spot (pits, rust) build up.
5		No discolor, stains, corrosion spot (pits, rust) build up.
6		No discolor, stains, corrosion spot (pits, rust) build up.
7		No discolor, stains, corrosion spot (pits, rust) build up.
8		No discolor, stains, corrosion spot (pits, rust) build up.
1	C1010	Light yellow coating. No corrosion (pits, rust) or stain.
2	METAL	No discolor, small scatter etch. No corrosion (pits/rust) or stains.
3		No discolor, several tiny etch. No corrosion (stain, pits, or rust)
4	MILD	No discolor, several tiny etching spots, no corrosion.
5	STEEL	No discolor, serveral etching spots, no corrosion (pits, stains or rust).
6		No discolor, scatter rust spots, pits or stains.
7		Various etches, light yellow coating on surface. No corrosion (pits/rust).
8		Various etches, light coating, no corrosion (pits/rust).
1	CDA 110	Brownish deposit film covered the entire specimen.
2	METAL	Brownish deposit film covered the entire specimen.
3		Brownish deposit film covered the entire specimen.
4	COPPER	Brownish deposit film covered the entire specimen.
5	ELECTROLYTE	Brownish deposit film covered the entire specimen.
6		Brownish deposit film covered the entire specimen.
7		Brownish deposit film covered the entire specimen.
8		Brownish deposit film covered the entire specimen.
1	CDA 443	Gray deposit film covered entire specimen.
2	METALS	Gray deposit film covered entire specimen.
3		Brownish deposit film covered entire specimen.
4	ADMIRABLY	Brownish deposit film covered entire specimen.
5	BRASS	Brownish deposit film covered entire specimen.
6		Brownish deposit film covered entire specimen.
7		Brownish deposit film covered entire specimen.
8		Brownish deposit film covered entire specimen.
1	ZINC	No discolor, some etching on various areas, no corrosion (pits/stains/rust).
2	ZIMACK 3	No discolor, light yellow caoting, no corrosion (pits/stain/rust).
3		No discolor, scatter of small etches along specimens edge.
4		No discolor, scatter small etches along specimen's edge.
5		No discolor, small stains on various area. No corrosion.
6		No discolor, small stain along edge, no corrosion.
7		No discolor, light yellowish deposit film on various areas. No corrosion.
8		No discolor, light yellowish deposit film on various areas. No corrosion.

TABLE II (cont.)

1	CADIUM	No discolor, no corrosion (spots, pits, stains or rust).
2	PLATE	No discolor, no corrosion (spots, pits, stains or rust).
3	ON STEEL	No discolor, no corrosion (spots, pits, stains or rust).
4		No discolor, no corrosion (spots, pits, stains or rust).
5		No discolor, no corrosion (spots, pits, stains or rust).
6		No discolor, no corrosion (spots, pits, stains or rust).
7		No discolor, no corrosion (spots, pits, stains or rust).
8		No discolor, no corrosion (spots, pits, stains or rust).
1	TERNE	No discolor, slight yellow deposit film, no corrosion (pits, stains, rust or spots).
2	COATING	No discolor, slight yellow deposit film, no corrosion (pits, stains, rust or spots).
3	ON STEEL	No discolor, slight yellow deposit film, no corrosion (pits, stains, rust or spots).
4		No discolor, slight yellow deposit film, no corrosion (pits, stains, rust or spots).
5		No discolor, general surface etching, no corrosion, pits or stains.
6		No discolor, various etching spots, no corrosion, pits, stains, rust or spots.
7		No discolor, light yellow deposit on surface. No corrosion, pits, stains, rust or spots
8		No discolor, light yellow deposit on surface. No corrosion, pits, stains, rust or spots

ELASTOMERS

TWELVE WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
NBR	1	483.0	1569.3	533.0	-3.7	4.1
ART 117	2	468.5	1532.8	550.0	1.4	5.2
	3	352.0	1225.6	617.0	-1.4	2.3
	4	290.0	1100.8	716.5	-6.7	3.7
	5	320.0	1297.6	817.0	-6.4	11.7
	6	282.0	1140.8	800.0	-6.5	10.3
	7	306.0	1203.2	700.0	-7.2	11.5
	8	314.0	1249.6	683.5	-8.2	12.3

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
HYDRIN	1	436.5	1227.2	450.0	-6.2	4.6
ART 146	2	430.0	1195.2	433.0	-4.3	5.4
	3	390.0	1126.4	467.0	-7.4	8.9
	4	398.0	1118.4	483.5	-6.2	7.5
	5	374.0	1032.0	450.0	-6.7	9.7
	6	374.0	1172.8	533.5	-8.0	10.5
	7	374.0	1211.2	483.5	-11.1	16.1
	8	398.0	1124.8	433.5	-10.4	17.1
AIR						

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
VITON (HI)	1	382.0	881.6	300.0	-10.4	10.2
ART 400	2	368.0	696.0	333.0	-11.3	11.1
	3	330.0	656.0	316.5	-8.7	11.4
	4	374.0	748.8	367.0	-8.6	11.6
	5	328.0	710.4	367.0	-10.7	15.0
	6	320.0	702.4	400.0	-11.8	14.5
	7	358.0	678.4	233.5	-8.7	12.0
	8	374.0	913.6	233.0	-7.5	9.3
AIR						

TWELVE WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
VITON (LO)	1	290.0	897.6	667.0	-4.1	12.1
ART 401	2	298.0	929.6	733.5	-2.7	11.8
	3	250.0	774.4	800.0	-2.7	15.8
	4	274.0	780.8	783.0	-4.7	16.9
	5	266.0	867.2	866.5	-5.4	18.7
	6	282.0	820.8	817.0	-7.3	17.4
	7	274.0	828.8	800.0	-5.4	16.3
	8	290.0	758.4	683.5	-5.3	17.2
AIR						

TYPE ELASTOMER	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL
URETHENE	1	382.0	1390.4	633.0	-4.4	12.1
ART 505	2	328.0	1438.4	850.0	-5.8	9.6
	3	250.0	1219.2	1083.0	-21.8	15.6
	4	266.0	1062.4	950.0	-19.4	14.6
	5	336.0	1328.0	783.0	-6.9	17.3
	6	322.0	1273.6	800.0	-9.4	17.9
	7	266.0	608.0	533.0	-26.9	15.5
	8	250.0	524.8	583.5	-31.0	12.2
AIR						

ETHYL FUEL COMPATABILITY TEST

TWELVE WEEK DATA

TYPE ELASTOMER	SPECIMEN NO.	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL	DUROMETER INITIAL	DUROMETER FINAL	WEIGHT INITIAL	WEIGHT FINAL	WEIGHT H2O INITIAL	WEIGHT H2O FINAL
IBR	5	1	* 813	1561.0	* 267	-3.5294	5.2491	85	82.0	4.6968	4.7519	0.98	0.84
RT 117	11	2	499	1532.8	533	2.7397	5.0080	73	75.0	3.8389	3.8776	0.67	0.55
	17	3	422	1404.8	467	1.2195	-0.4763	82	83.0	4.6444	4.5369	0.97	0.88
	23	4	266	1046.4	733	-7.8947	4.1956	76	70.0	4.1484	4.2135	0.69	0.61
	29	5	298	1267.2	867	-6.4935	11.8865	77	72.0	4.3198	4.5865	0.73	0.57
	35	6	314	1219.2	767	-6.3291	10.0619	79	74.0	4.0174	4.2322	0.69	0.57
	41	7	314	1155.2	700	-9.3333	14.4831	75	68.0	4.0912	4.4238	0.69	0.53
	47	8	314	1203.2	667	-7.7922	15.2171	77	71.0	4.1088	4.4560	0.71	0.54
BR	6	1	483	1577.6	533	-3.8462	3.0167	78	75.0	4.0780	4.1393	0.72	0.68
RT 117	12	2	438	1532.8	567	0.0000	5.4539	75	75.0	3.9792	4.0275	0.71	0.58
	18	3	282	1046.4	767	-4.1096	4.9969	73	70.0	4.0441	4.1117	0.69	0.59
	24	4	314	1155.2	700	-5.4054	3.2694	74	70.0	4.0484	4.0782	0.69	0.61
	30	5	342	1328.0	767	-6.3291	11.5052	79	74.0	4.2471	4.5129	0.72	0.58
	36	6	250	1062.4	833	-6.6667	10.5094	75	70.0	4.1079	4.3471	0.69	0.57
	42	7	298	1251.2	700	-5.1282	8.5389	78	74.0	3.7875	3.9137	0.67	0.53
	48	8	314	1296.0	700	-8.6420	9.3476	81	74.0	3.8876	4.0565	0.69	0.56
YDRIN	5	1	467	1219.2	433	-6.2500	4.9847	80	75.0	6.5254	6.6440	2.14	2.04
RT 146	11	2	406	1203.2	433	-3.7500	5.7579	80	77.0	6.6382	6.7649	2.18	2.05
	17	3	390	1126.4	467	-7.4074	8.9662	81	75.0	6.5788	6.7850	2.16	1.97
	23	4	422	1126.4	467	-6.2500	8.1133	80	75.0	6.4610	6.6632	2.12	1.97
	29	5	374	1110.4	500	-7.3171	9.9564	82	76.0	6.5414	6.8296	2.14	1.99
	35	6	358	1126.4	567	-8.6420	10.7493	81	74.0	6.1780	6.4339	2.03	1.84
	41	7	342	1187.2	500	-11.1111	16.2575	81	72.0	6.5485	7.0124	2.16	1.91
	47	8	390	1187.2	467	-9.8765	17.1634	81	73.0	6.6862	7.1979	2.19	1.93
YDRIN	6	1	406	1235.2	467	-6.1728	4.3092	81	76.0	6.5594	6.6250	2.15	2.03
RT 146	12	2	454	1187.2	433	-4.9383	5.1155	81	77.0	6.5737	6.6900	2.15	2.04
	18	3	390	1126.4	467	-7.4074	8.7897	81	75.0	6.5099	6.7240	2.14	1.97
	24	4	374	1110.4	500	-6.1728	6.9153	81	76.0	6.3718	6.5179	2.09	1.94
	30	5	374	953.6	400	-6.1728	9.3903	81	76.0	6.0072	6.2559	1.97	1.84
	36	6	390	1219.2	500	-7.4074	10.2704	81	75.0	6.5442	6.8155	2.15	1.97
	42	7	406	1235.2	467	-11.1111	15.9462	81	72.0	6.5692	7.0323	2.16	1.92
	48	8	406	1062.4	400	-10.9756	16.9809	82	73.0	6.4796	6.9582	2.13	1.87
VITON (hi)	5	1	390	1014.4	333	-8.5366	10.5563	82	75.0	7.1231	7.4009	3.26	3.13
RT 400	11	2	422	812.8	233	-8.7500	10.6816	80	73.0	7.1096	7.3908	3.26	3.13
	17	3	330	688.0	333	-7.5000	11.2223	80	74.0	7.3182	7.6424	3.36	3.24
	23	4	374	748.8	367	-8.6420	11.8912	81	74.0	7.3142	7.6444	3.36	3.22
	29	5	282	531.2	367	-12.6582	15.9247	79	69.0	7.4403	7.9053	3.39	3.21
	35	6	374	889.6	367	-8.6420	13.7447	81	74.0	6.8338	7.1915	3.14	2.99
	41	7	342	732.8	267	-7.5000	11.8290	80	74.0	7.0428	7.3450	3.22	3.07
	47	8	374	1155.2	667	-7.4074	6.7364	81	75.0	7.4270	7.4076	3.41	3.12

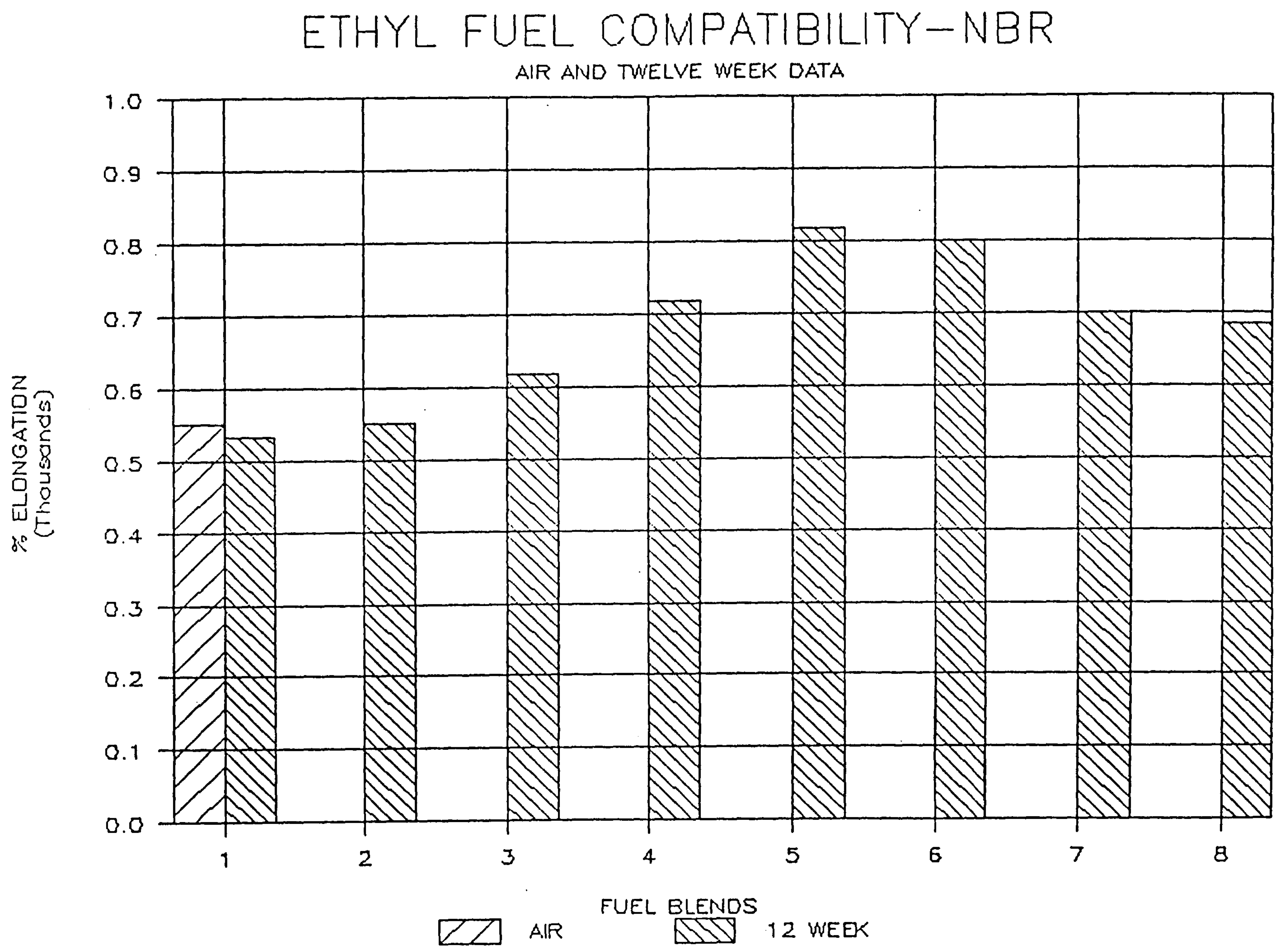
*) DATA NOT SUMMARIZED

ETHYL FUEL COMPATABILITY TEST

TWELVE WEEK DATA

TYPE ELASTOMER	SPECIMEN NO.	FUEL BLEND	100% MODULUS	TENSILE	% ELONG	% CHANGE HARDNESS	% VOLUME SWELL	DUROMETER INITIAL	DUROMETER FINAL	WEIGHT INITIAL	WEIGHT FINAL	WEIGHT H20 INITIAL	WEIGHT H20 FINAL
VITON (hi)	6	1	374	748.8	267	-12.1951	9.8375	82	72.0	6.4570	6.7020	2.95	2.85
ART 400	12	2	314	579.2	433	-13.7500	11.4258	80	69.0	6.6080	6.8991	3.01	2.89
	18	3	330	624.0	300	-9.8765	11.5166	81	73.0	6.7682	7.0595	3.11	2.98
	24	4	374	748.8	367	-8.6420	11.2773	81	74.0	7.1686	7.4860	3.29	3.17
	30	5	374	889.6	367	-8.7500	14.0732	80	73.0	7.3691	7.7819	3.37	3.22
	36	6	266	515.2	433	-15.0000	15.2486	80	68.0	7.0387	7.4510	3.22	3.05
	42	7	374	624.0	200	-9.8765	12.1190	81	73.0	7.5842	7.9228	3.47	3.31
	48	8	374	672.0	233	-7.5000	11.9617	80	74.0	7.4270	7.7575	3.41	3.26
VITON (lo)	5	1	298	873.6	667	-5.4054	7.5839	74	70	6.6774	6.7225	3.05	2.82
ART 401	11	2	314	921.6	767	-1.3699	11.6714	73	72	6.2752	6.5738	2.86	2.76
	17	3	266	828.8	833	-2.7027	15.3571	74	72	6.4361	6.8430	2.94	2.81
	23	4	266	732.8	733	-5.3333	16.9374	75	71	6.3650	6.7868	2.93	2.77
	29	5	266	873.6	833	-5.4054	18.6976	74	70	6.6112	7.0908	3.03	2.84
	35	6	282	860.8	867	-8.0000	17.3719	75	69	6.6913	7.1556	3.04	2.87
	41	7	282	812.8	767	-4.0541	16.3675	74	71	6.4390	6.8517	2.94	2.78
	47	8	298	796.8	767	-5.3333	16.6028	75	71	6.0474	6.4432	2.76	2.61
VITON (lo)	6	1	282	921.6	667	-2.7397	16.6700	73	71	6.4087	6.9886	2.93	2.93
ART 401	12	2	282	937.6	700	-4.0000	11.9150	75	72	6.7368	7.0537	3.07	2.95
	18	3	234	720.0	767	-2.7397	16.2692	73	71	6.0392	6.4227	2.76	2.61
	24	4	282	828.8	833	-4.0541	16.9564	74	71	6.6840	7.1285	3.06	2.89
	30	5	266	860.8	900	-5.4054	18.7936	74	70	6.0906	6.5309	2.79	2.61
	36	6	282	780.8	767	-6.6667	17.4348	75	70	6.4657	6.9104	2.94	2.77
	42	7	266	844.8	833	-6.6667	16.2634	75	70	6.5309	6.9602	2.97	2.82
	48	8	282	720.0	600	-5.3333	17.7614	75	71	6.3613	6.7943	2.91	2.73
URETHENE	5	1	358	1500.8	733	-5.0633	12.0636	79	75	4.3256	4.6292	0.98	0.88
ART 505	11	2	342	1376.0	767	-6.4103	6.7552	78	73	4.2552	4.3832	0.88	0.78
	17	3	234	1376.0	1333	-22.7848	14.5442	79	61	4.5090	4.8879	1.01	0.88
	23	4	266	1110.4	1067	-19.2308	14.9873	78	63	4.4089	4.7828	0.98	0.84
	29	5	298	1344.0	833	-6.2500	16.7078	80	75	4.1698	4.6011	0.93	0.82
	35	6	330	1267.2	733	-11.2500	17.2628	80	71	4.2083	4.6425	0.94	0.81
	41	7	266	608.0	533	-26.9231	15.7977	78	57	4.3548	4.7190	0.91	0.73
	47	8	250	595.2	600	-29.4872	12.1378	78	55	4.0843	4.3193	0.83	0.67
URETHENE	6	1	406	1280.0	533	-3.7500	12.1873	80	77	4.2380	4.5475	0.96	0.87
ART 505	12	2	314	1500.8	933	-5.1948	12.5438	77	73	4.2442	4.5662	0.88	0.78
	18	3	266	1062.4	833	-20.7792	16.5661	77	61	4.3036	4.7391	0.89	0.76
	24	4	266	1014.4	833	-19.4805	14.1864	77	62	4.2211	4.5765	0.87	0.75
	30	5	374	1312.0	733	-7.5949	17.9368	79	73	4.4638	4.9333	1.01	0.86
	36	6	314	1280.0	867	-7.5949	18.6267	79	73	4.1336	4.5915	0.87	0.72
	42	7	266	608.0	533	-26.9231	15.2447	78	57	4.2984	4.6460	0.89	0.72
	48	8	250	454.4	567	-32.4675	12.2606	77	52	4.0101	4.2200	0.83	0.65

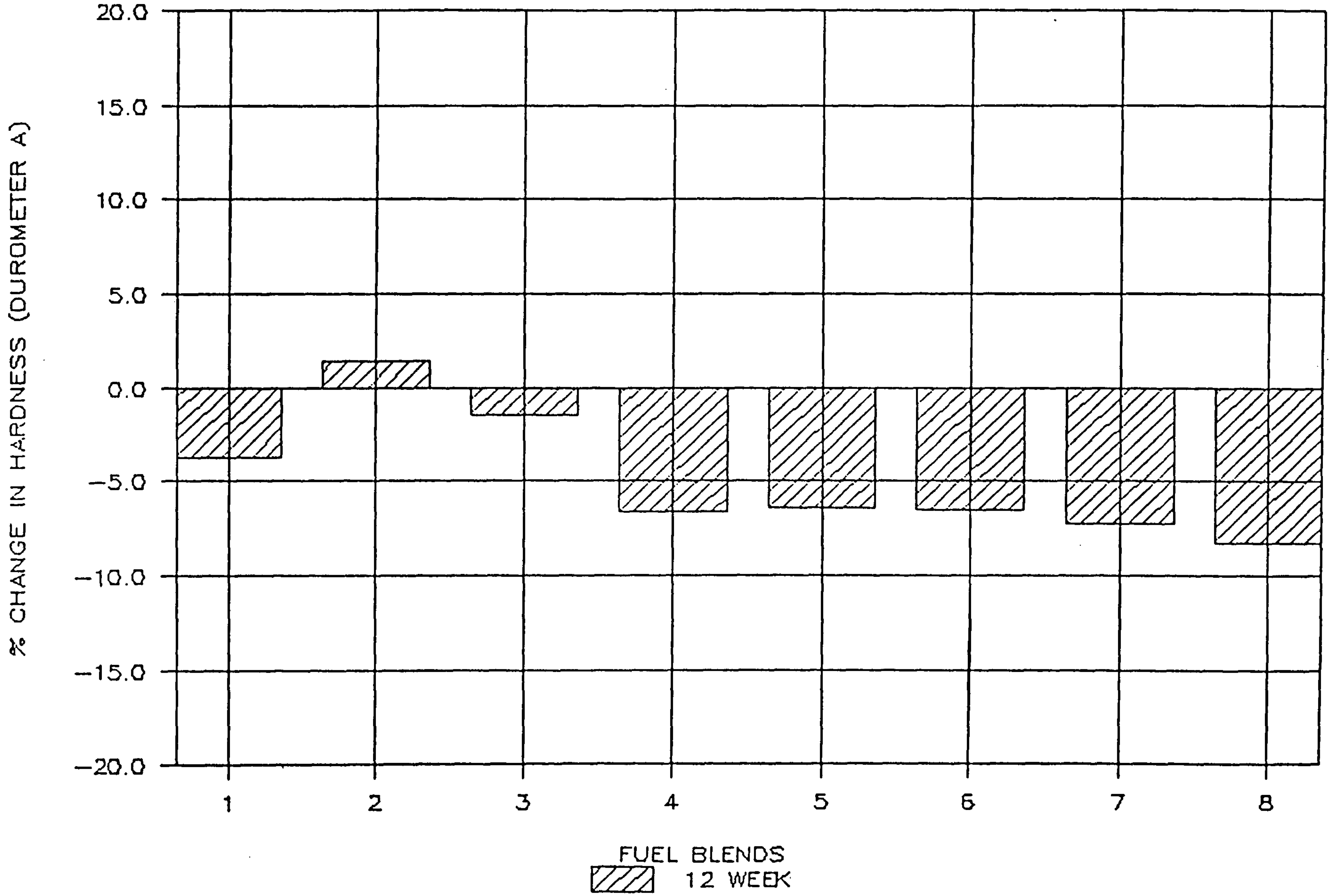
*) DATA NOT SUMMARIZED

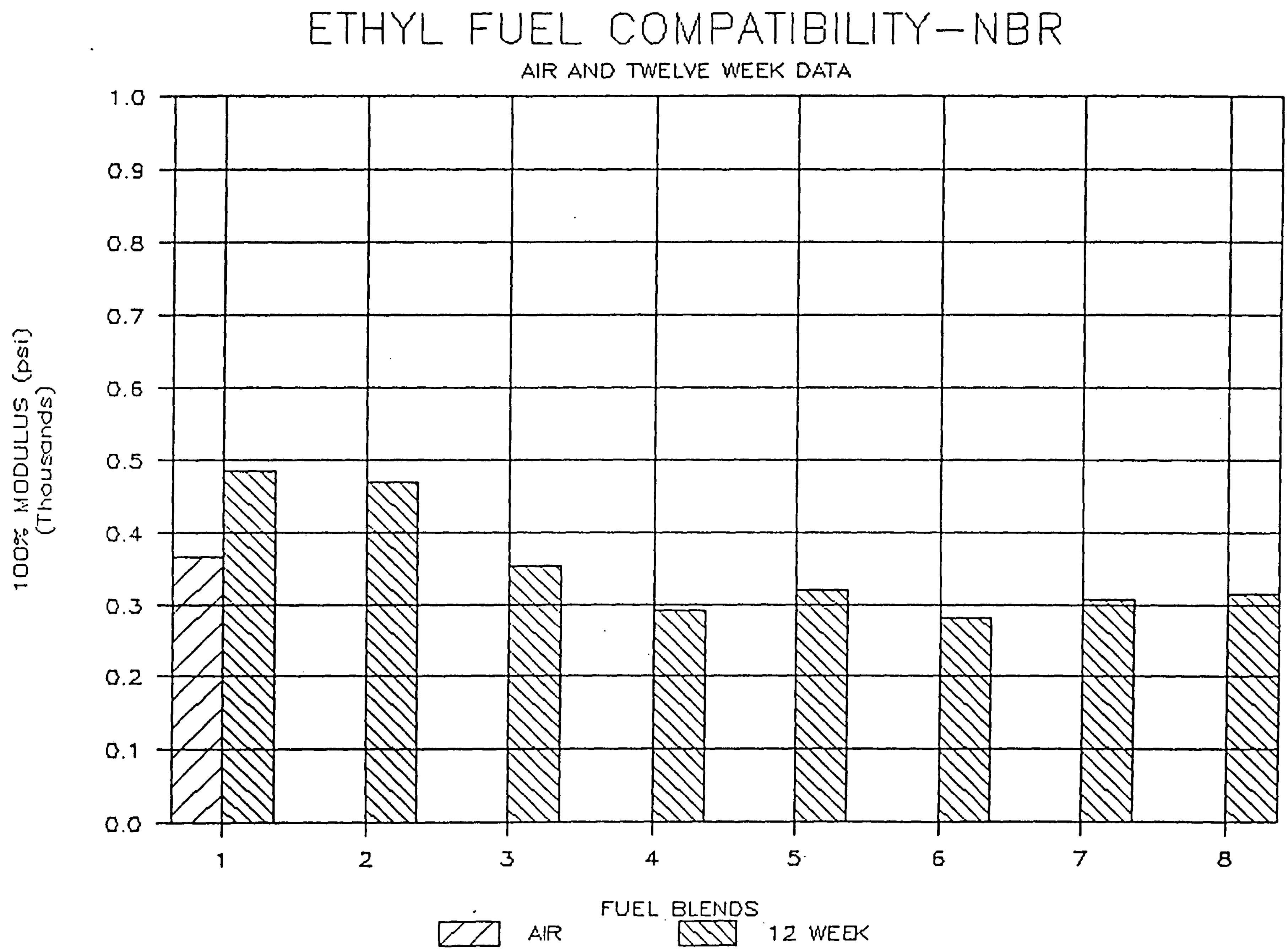


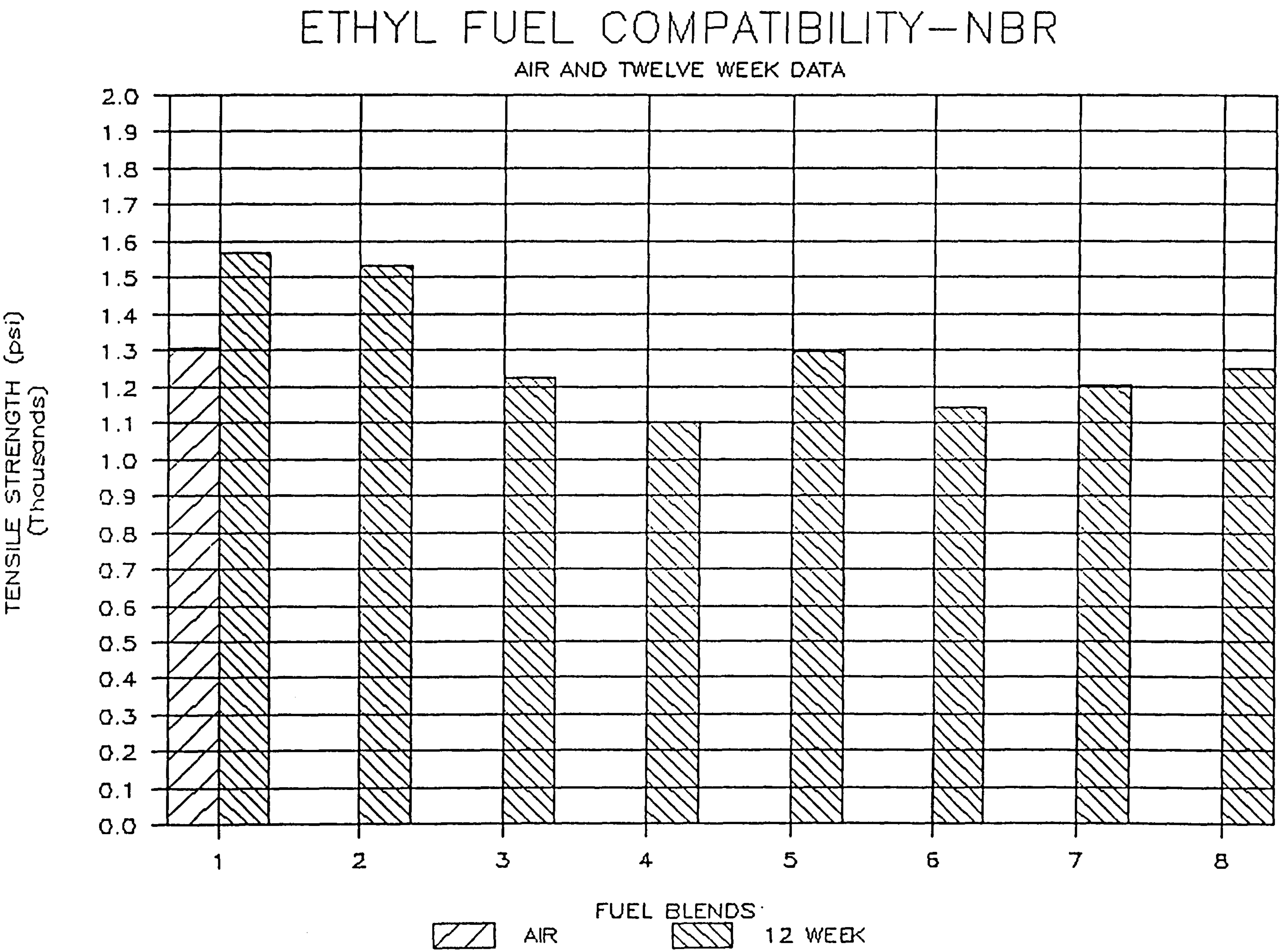
ETHYL FUEL COMPATIBILITY—NBR
AIR AND TWELVE WEEK DATA
% ELONGATION
(Thousands)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

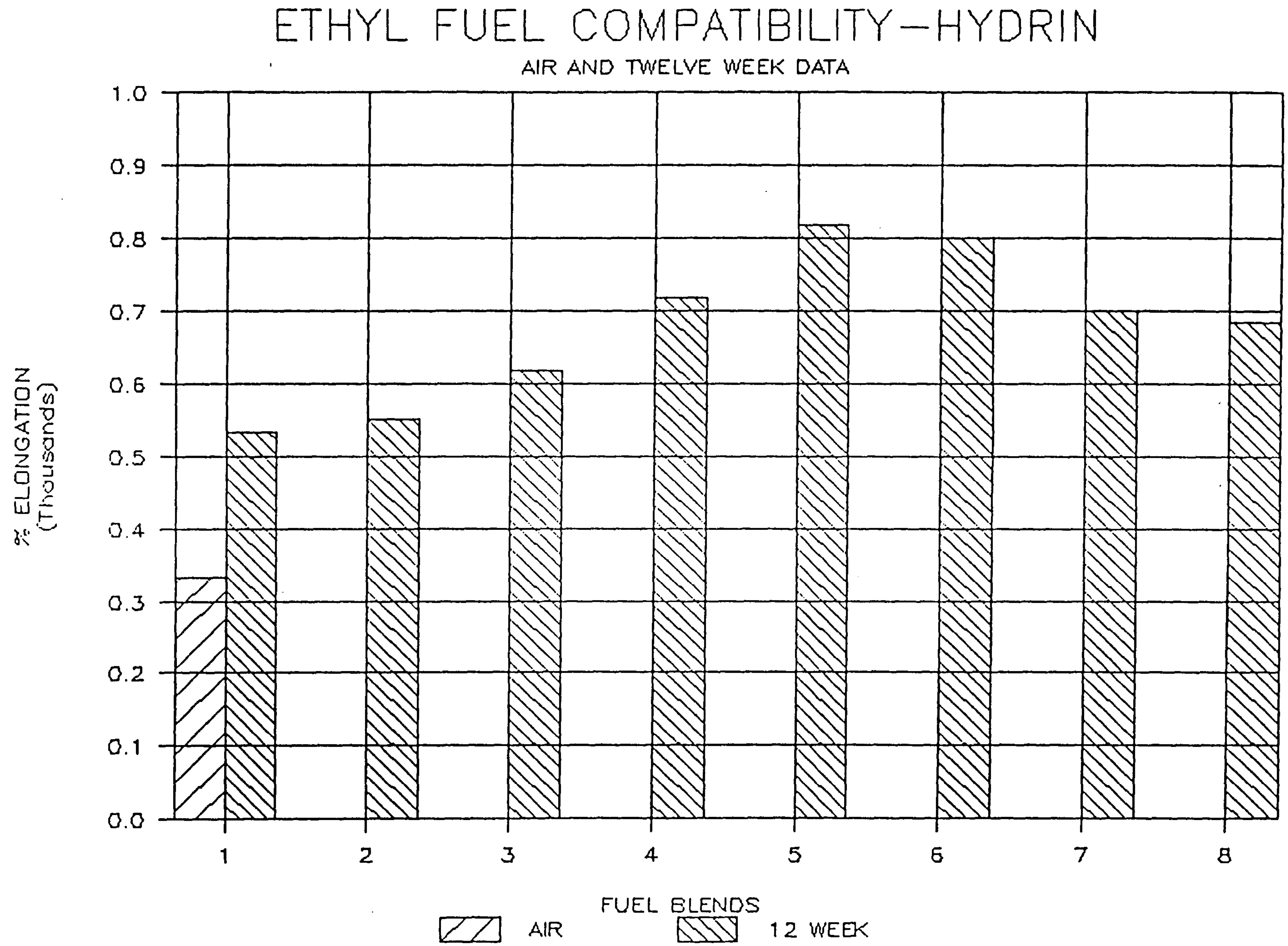
ETHYL FUEL COMPATIBILITY—NBR

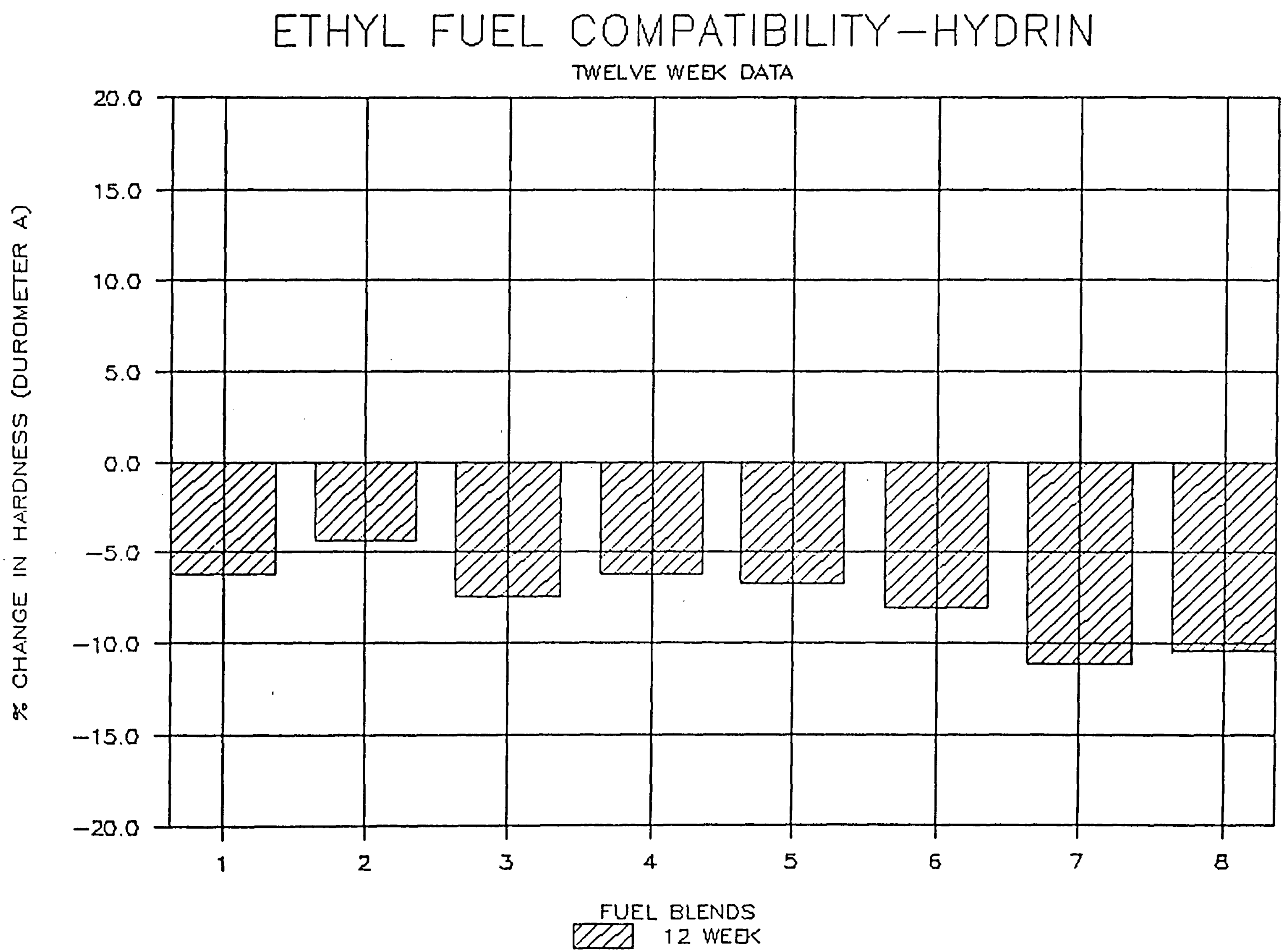
TWELVE WEEK DATA

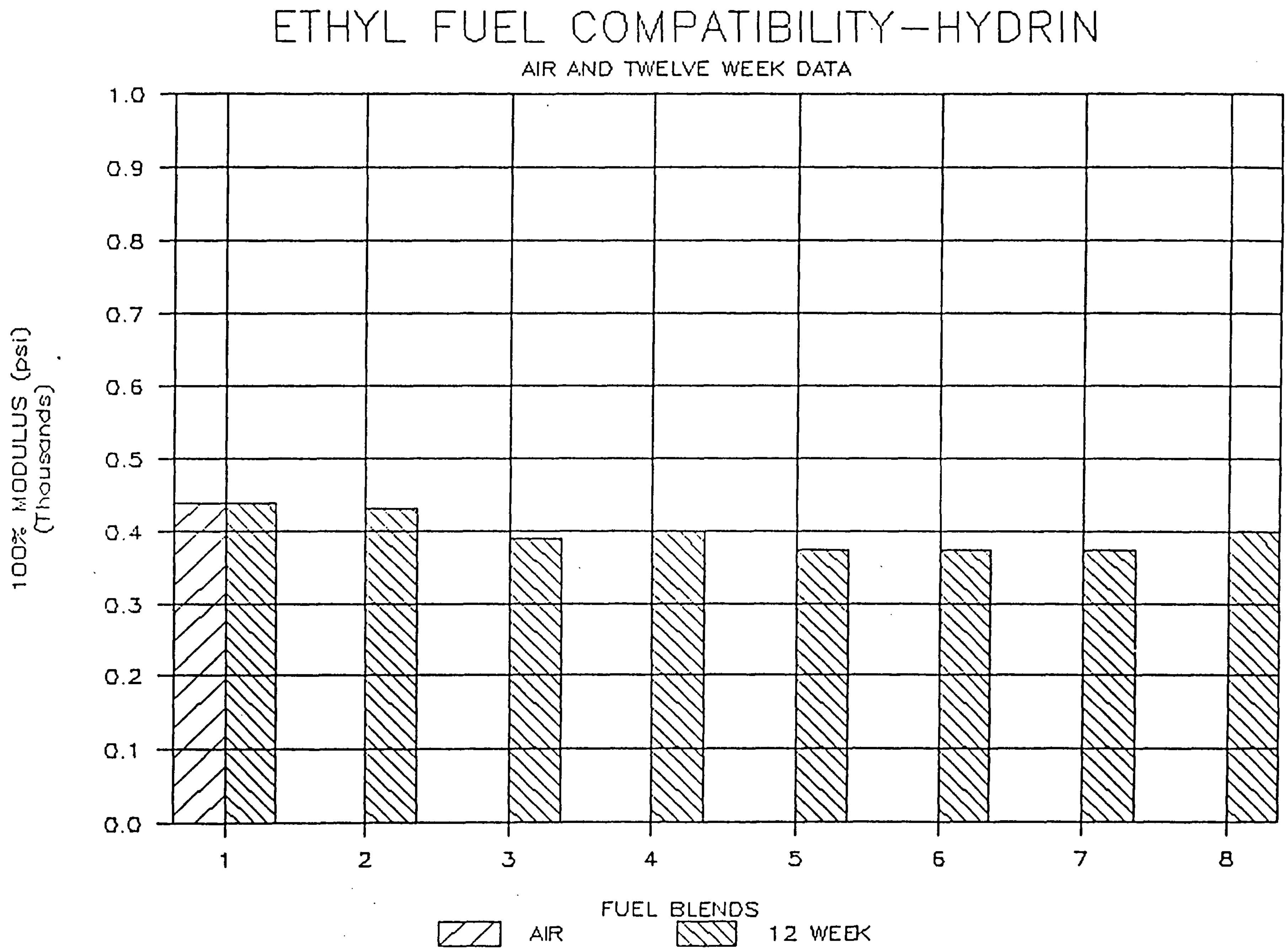



ETHYL FUEL COMPATIBILITY–NBR
AIR AND TWELVE WEEK DATA
100% MODULUS (psi)
(Thousands)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK


ETHYL FUEL COMPATIBILITY–NBR
AIR AND TWELVE WEEK DATA
TENSILE STRENGTH (psi)
(Thousands)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

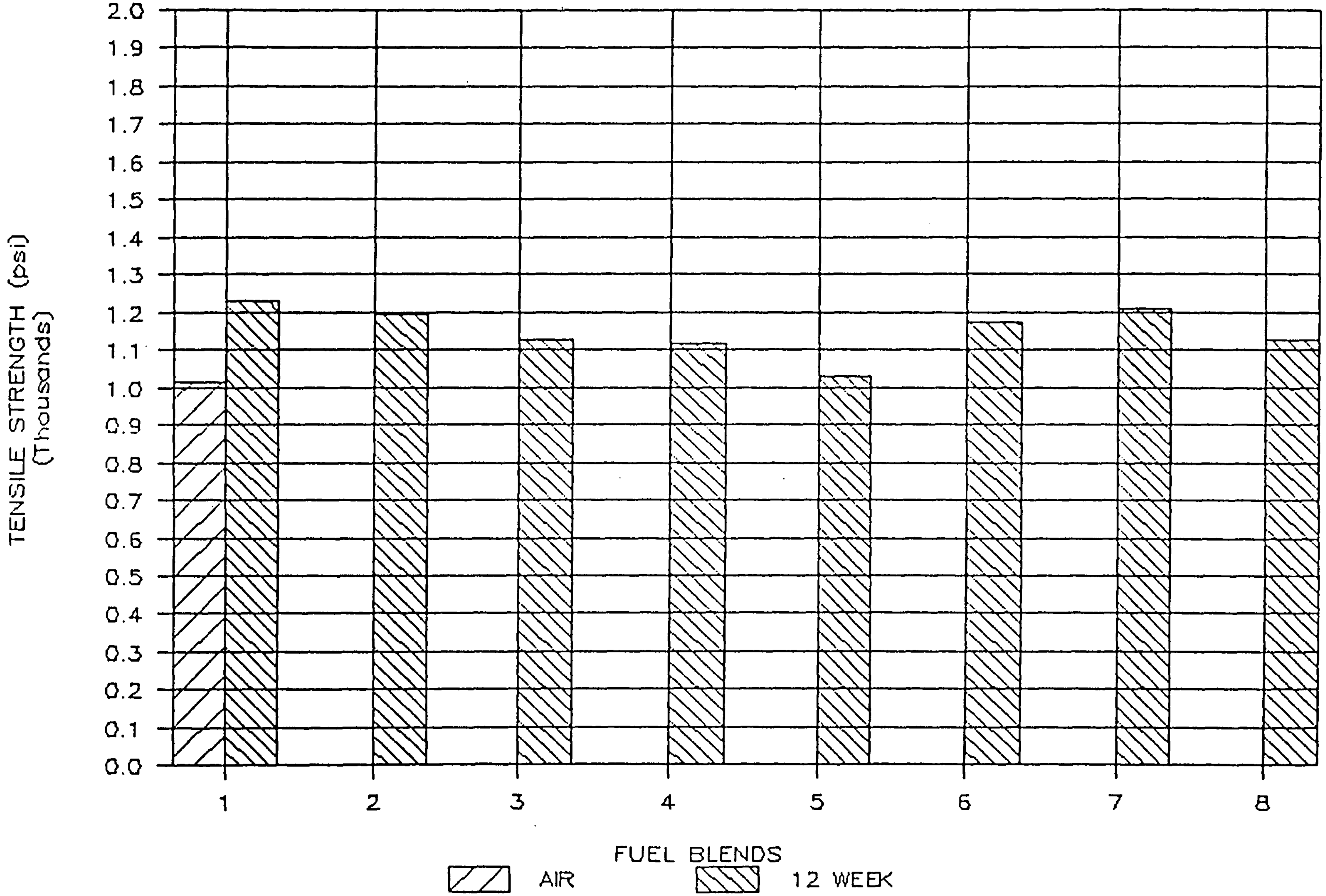

ETHYL FUEL COMPATIBILITY–HYDRIN
AIR AND TWELVE WEEK DATA
% ELONGATION (Thousands)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK


ETHYL FUEL COMPATIBILITY-HYDRIN
TWELVE WEEK DATA
% CHANGE IN HARDNESS (DUROMETER A)
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
1
2
3
4
5
6
7
8
FUEL BLENDS
12 WEEK


ETHYL FUEL COMPATIBILITY–HYDRIN
AIR AND TWELVE WEEK DATA
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
100% MODULUS (psi)
(Thousands)
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

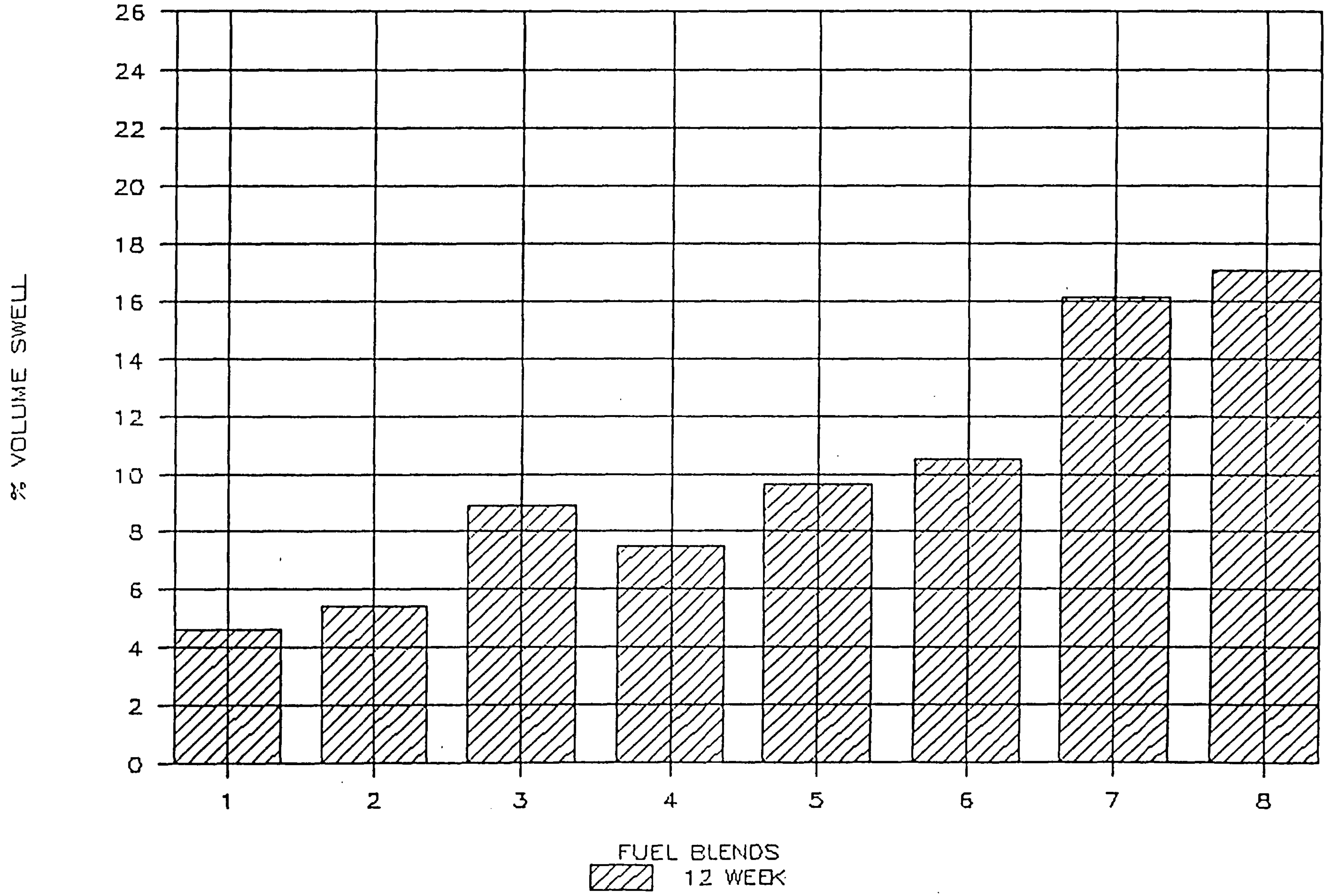
ETHYL FUEL COMPATIBILITY—HYDRIN

AIR AND TWELVE WEEK DATA



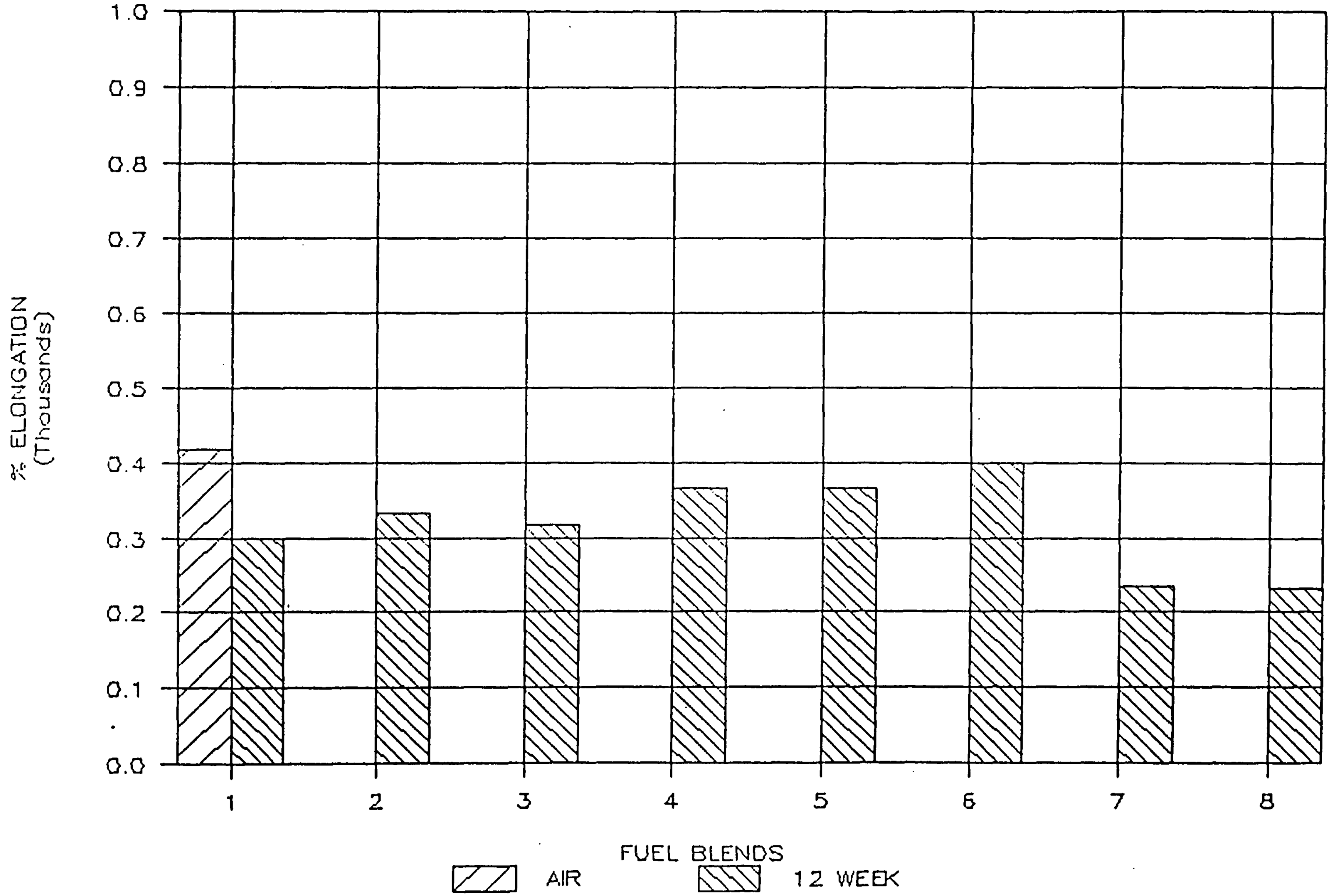
ETHYL FUEL COMPATIBILITY—HYDRIN

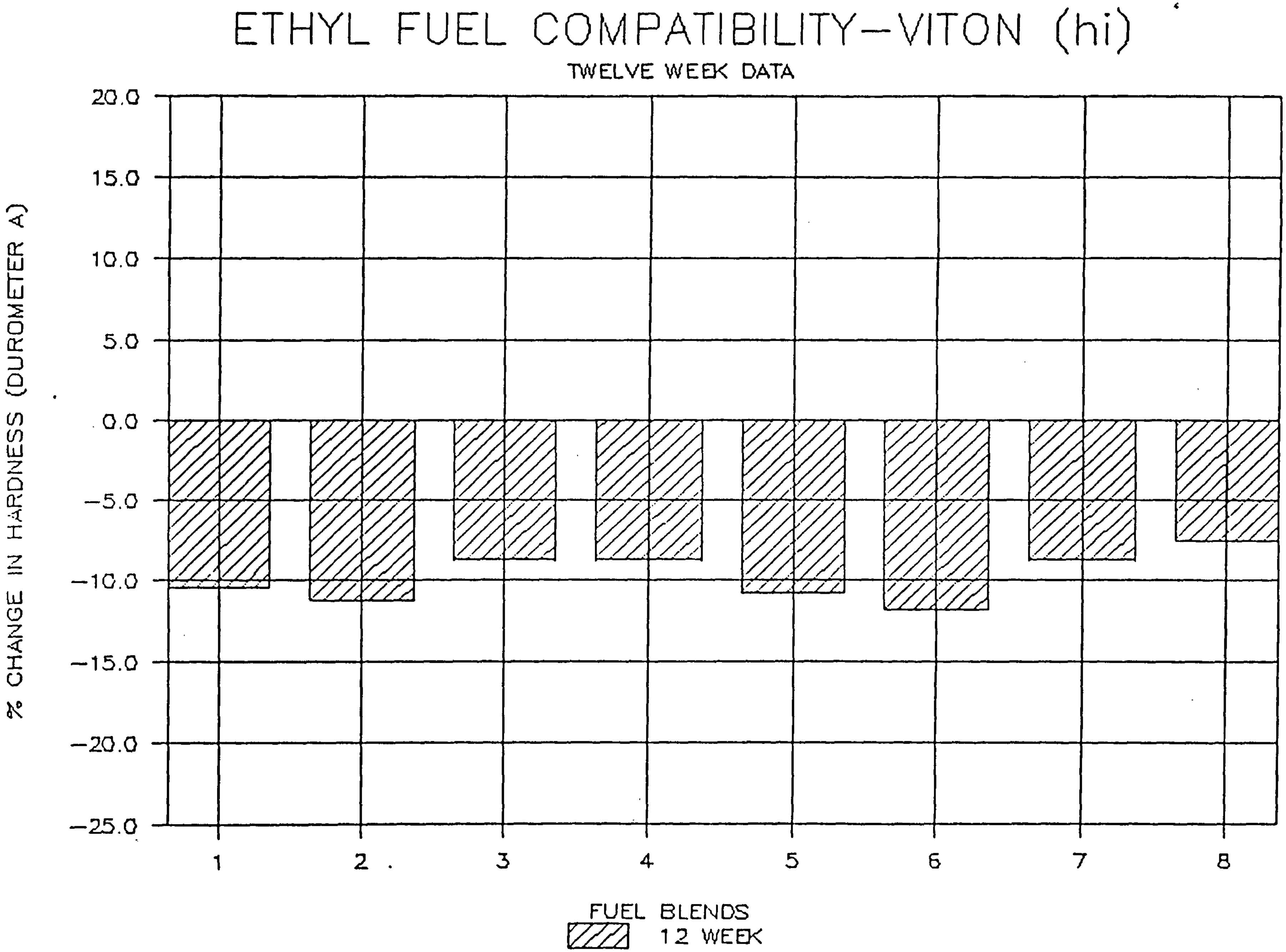
TWELVE WEEK DATA



ETHYL FUEL COMPATIBILITY—VITON (hi)

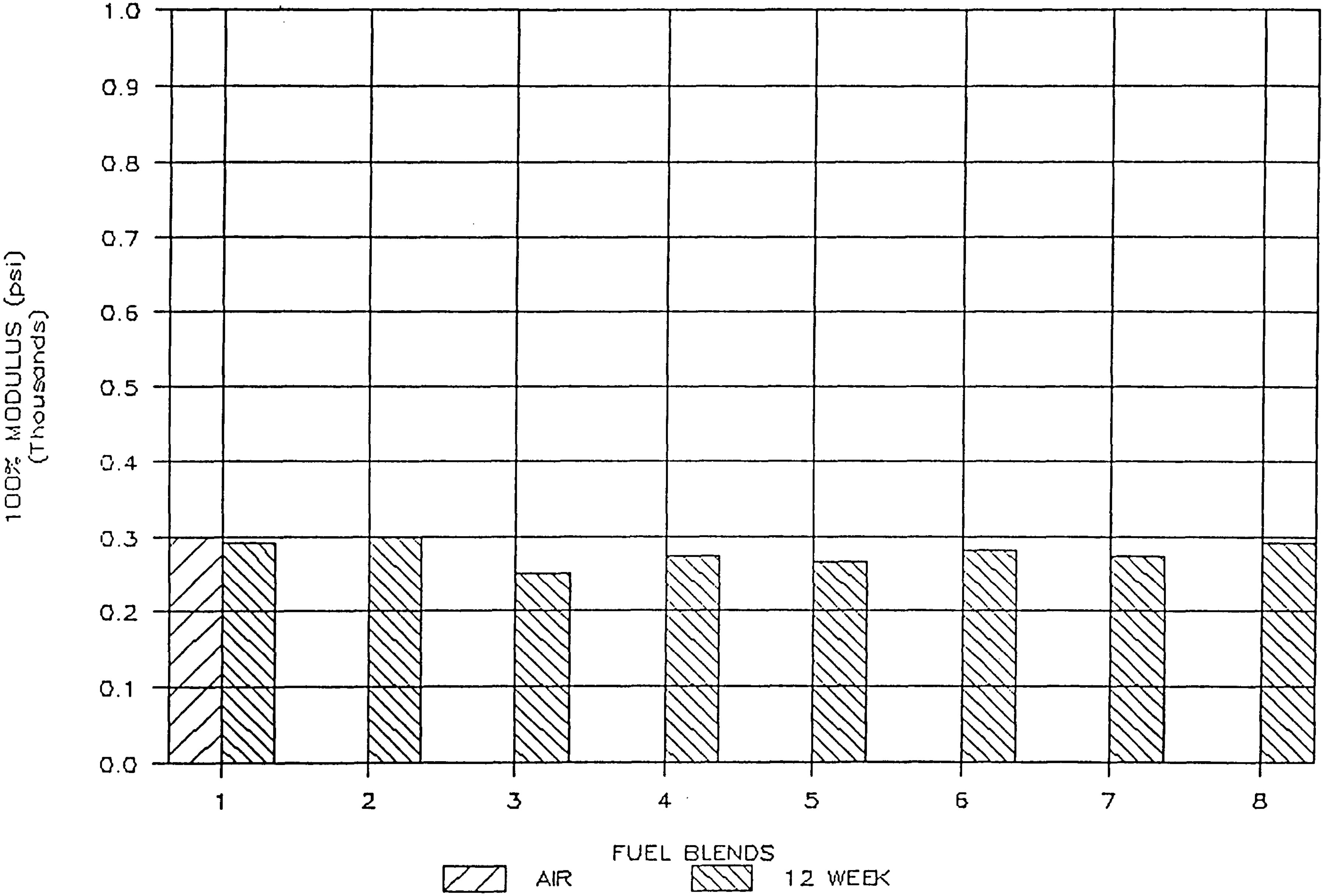
AIR AND TWELVE WEEK DATA

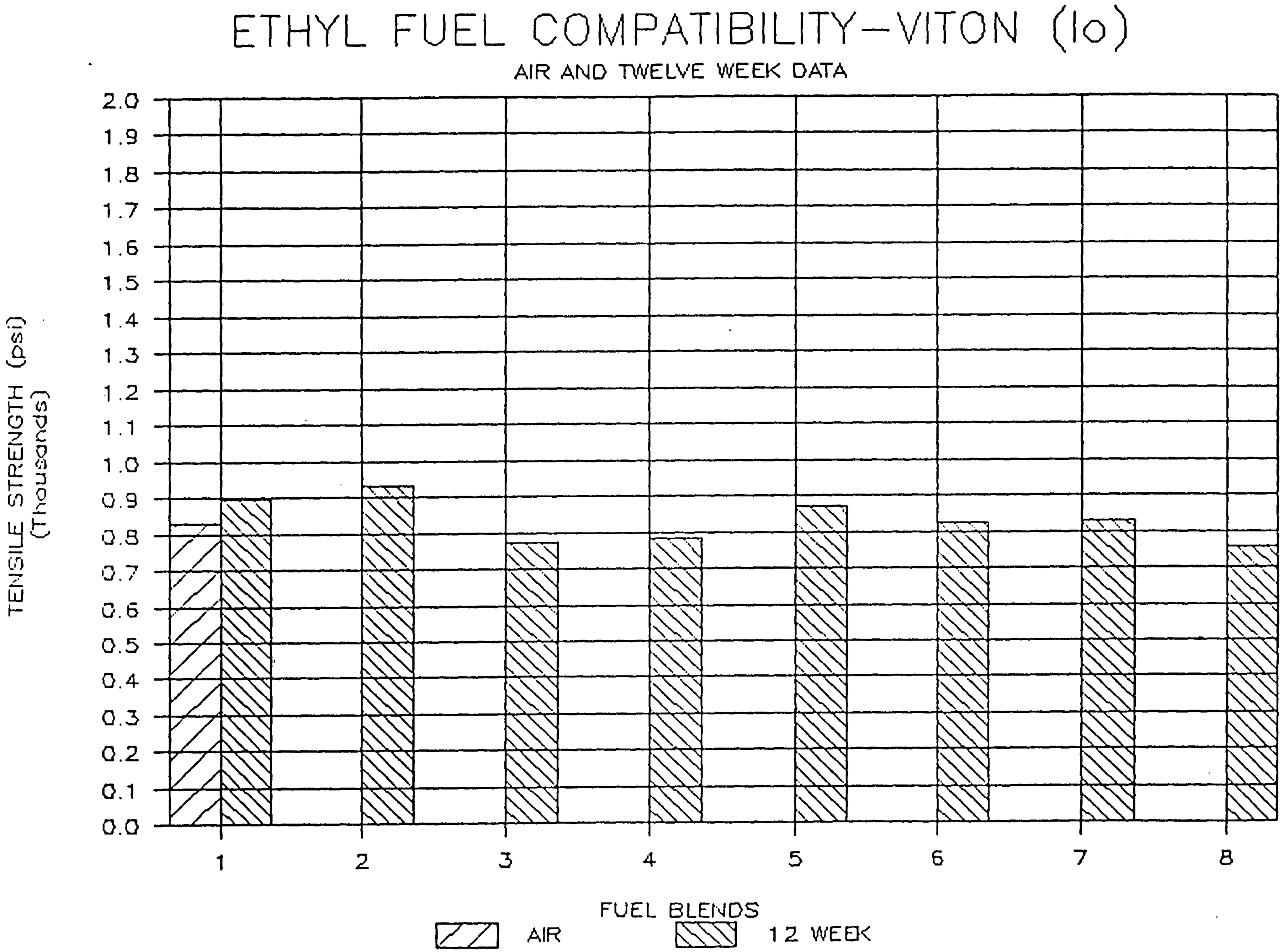



ETHYL FUEL COMPATIBILITY–VITON (hi)
TWELVE WEEK DATA
% CHANGE IN HARDNESS (DUROMETER A)
20.0
15.0
10.0
5.0
0.0
–5.0
–10.0
–15.0
–20.0
–25.0
1
2
3
4
5
6
7
8
FUEL BLENDS
12 WEEK

ETHYL FUEL COMPATIBILITY—VITON (Io)

AIR AND TWELVE WEEK DATA

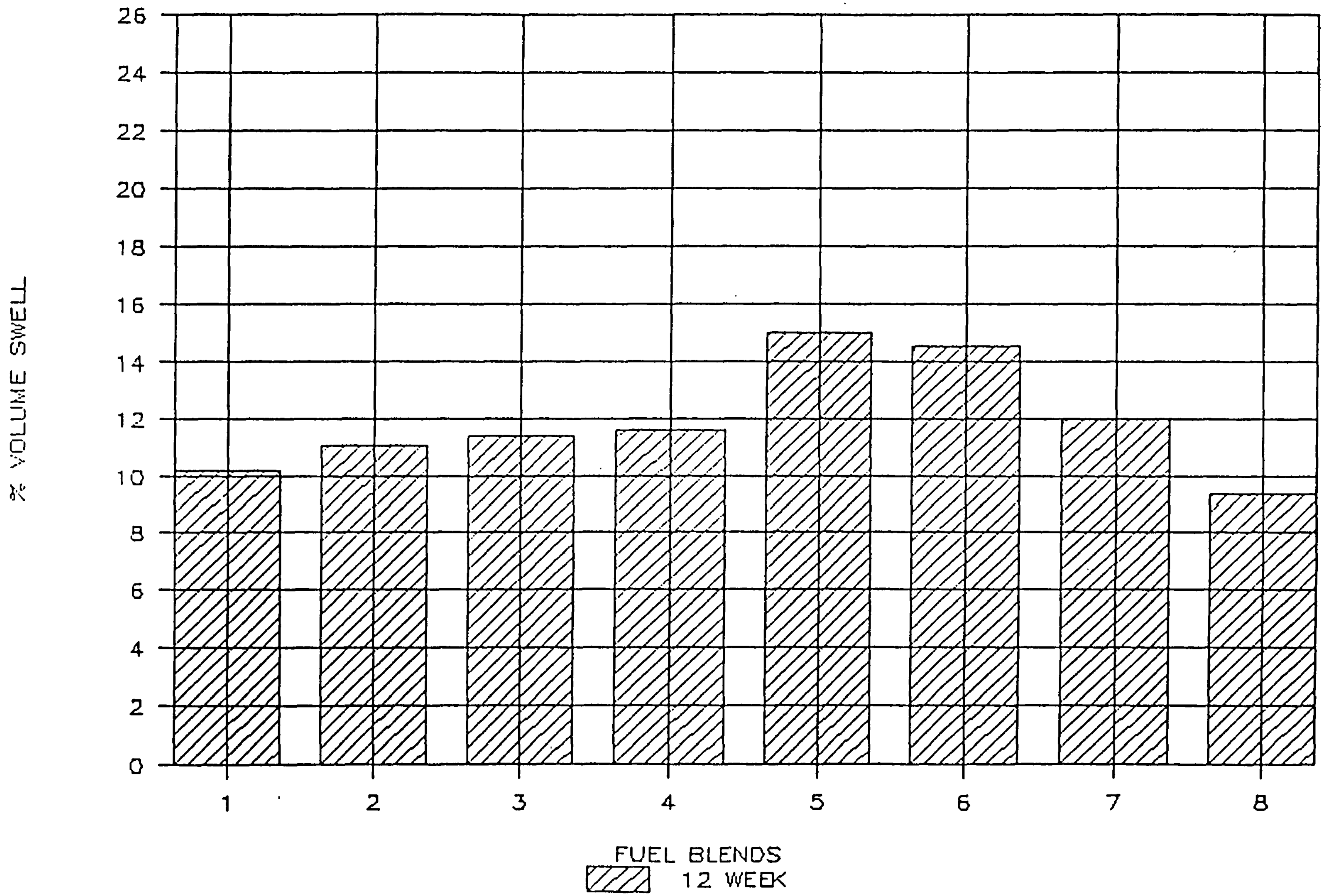


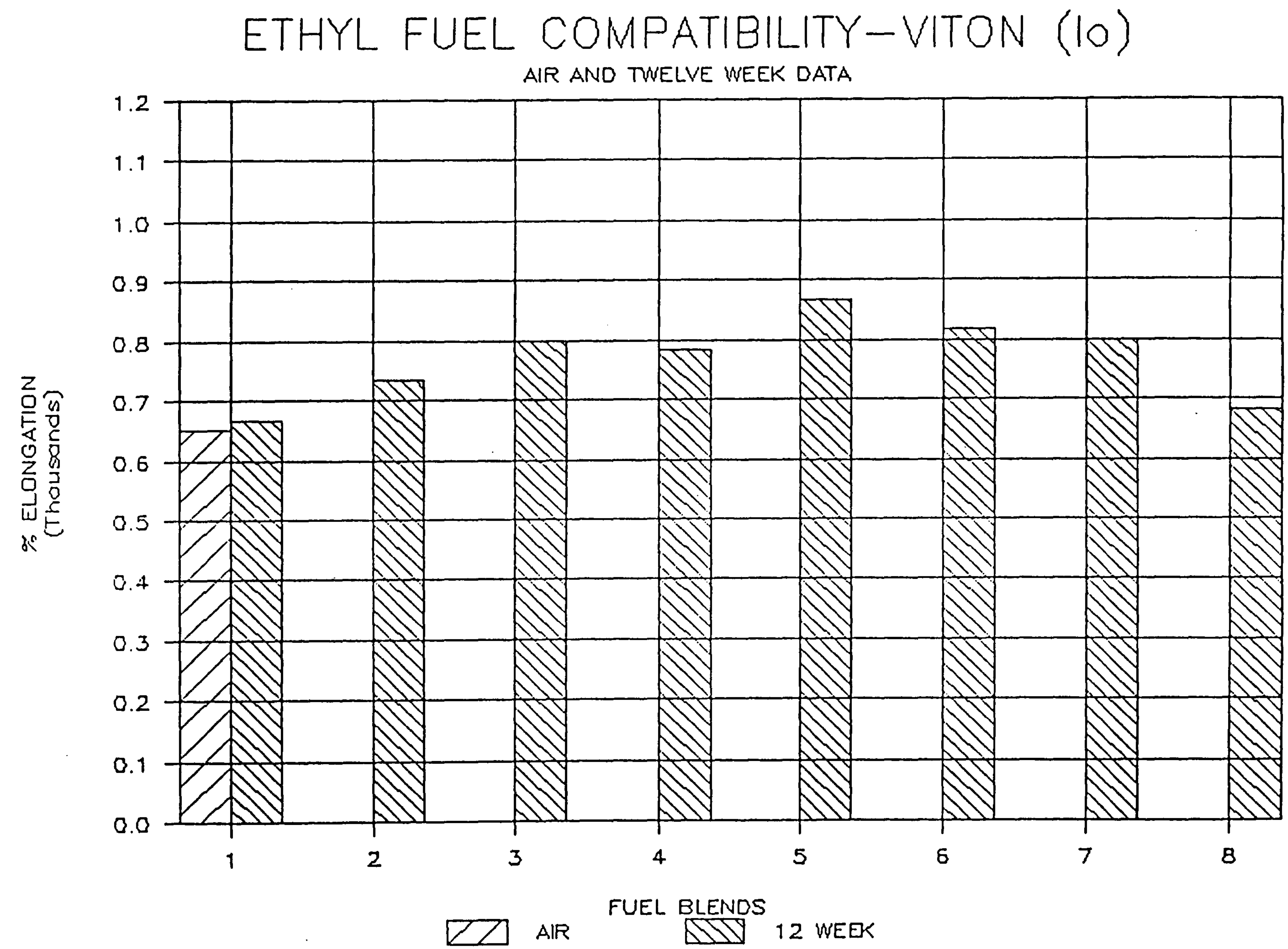


ETHYL FUEL COMPATIBILITY—VITON (lo)
AIR AND TWELVE WEEK DATA
TENSILE STRENGTH (psi)
(Thousands)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

ETHYL FUEL COMPATIBILITY–VITON (hi)

TWELVE WEEK DATA

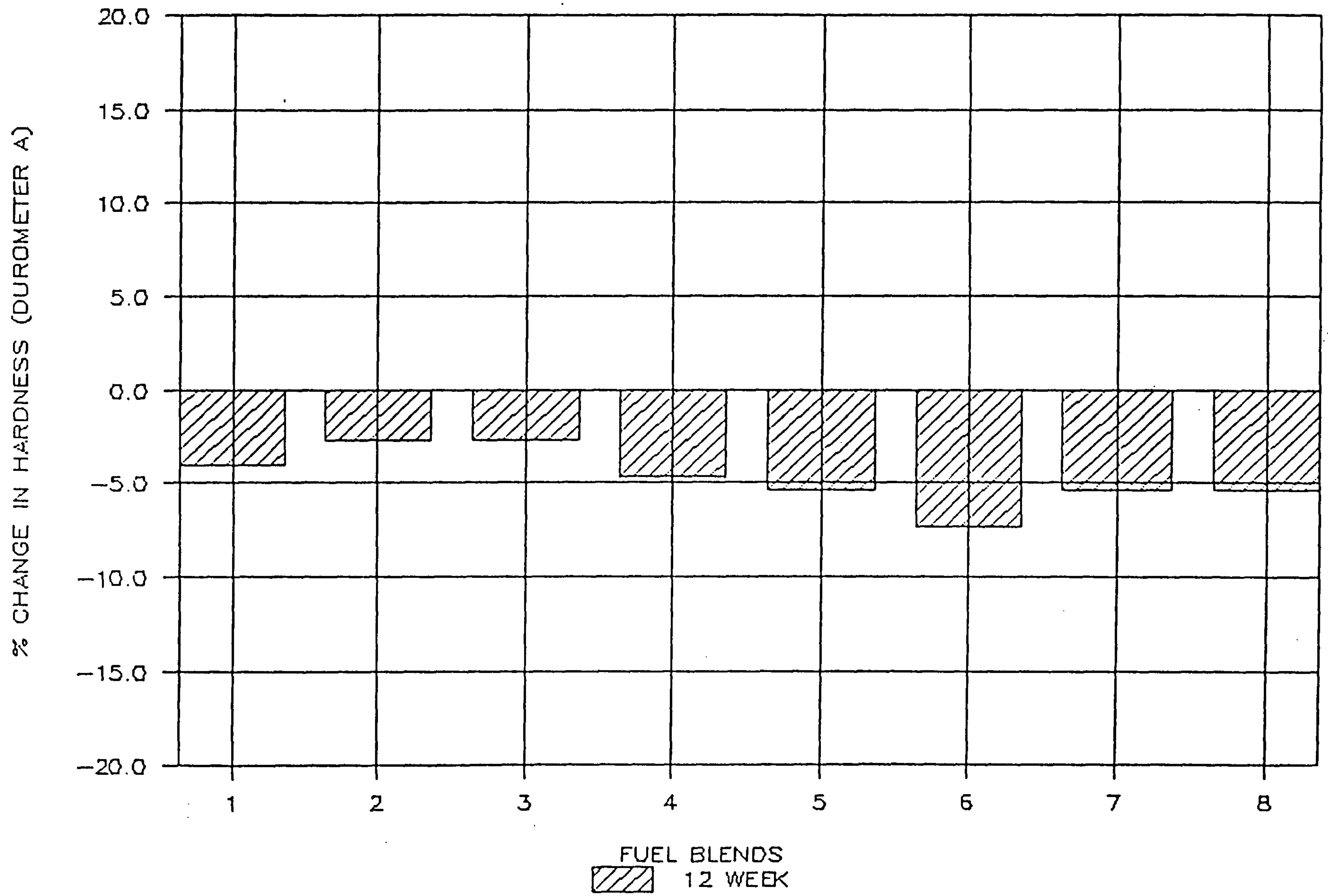




ETHYL FUEL COMPATIBILITY—VITON (Io)
AIR AND TWELVE WEEK DATA
% ELONGATION
(Thousands)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

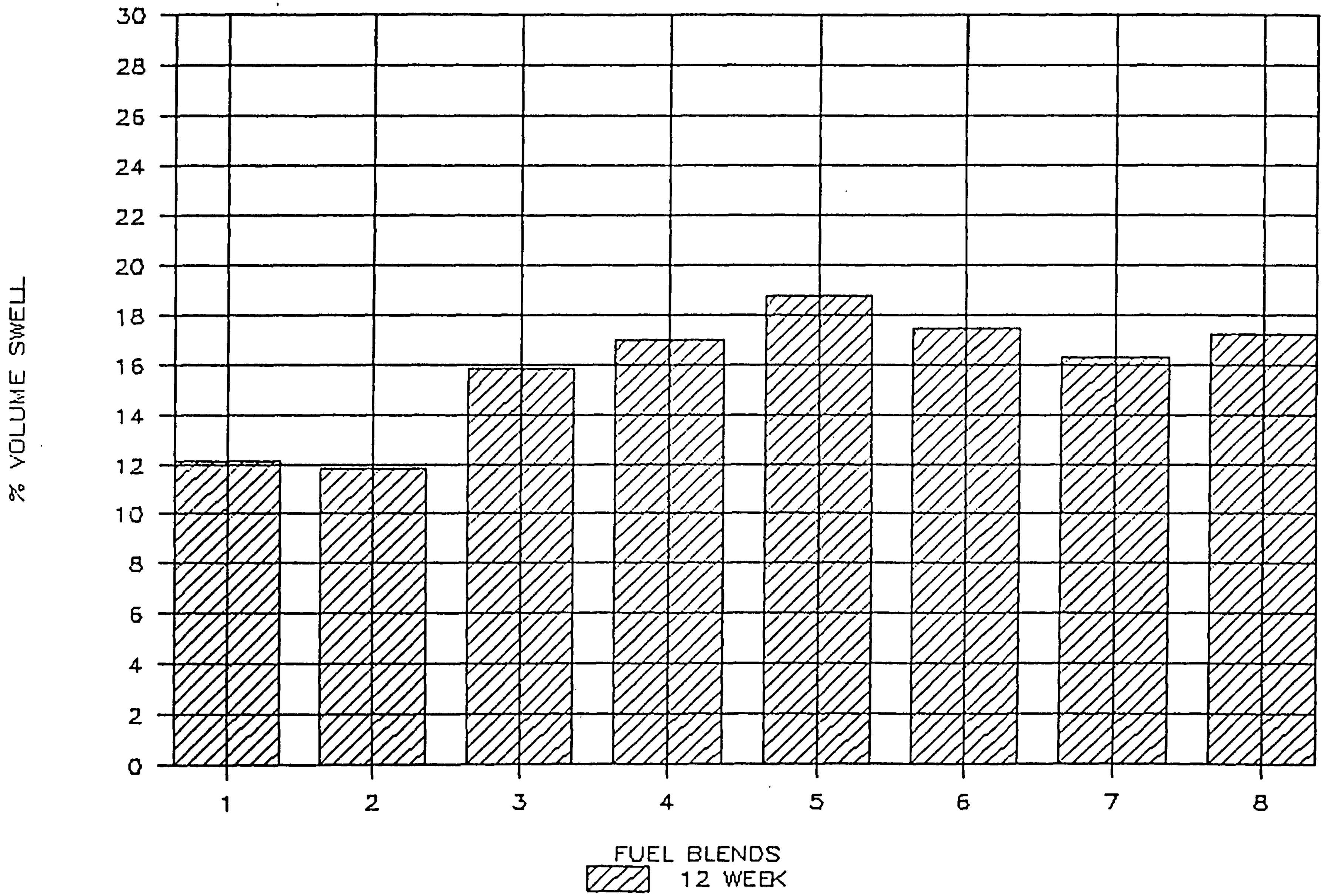
ETHYL FUEL COMPATIBILITY—VITON (Io)

TWELVE WEEK DATA



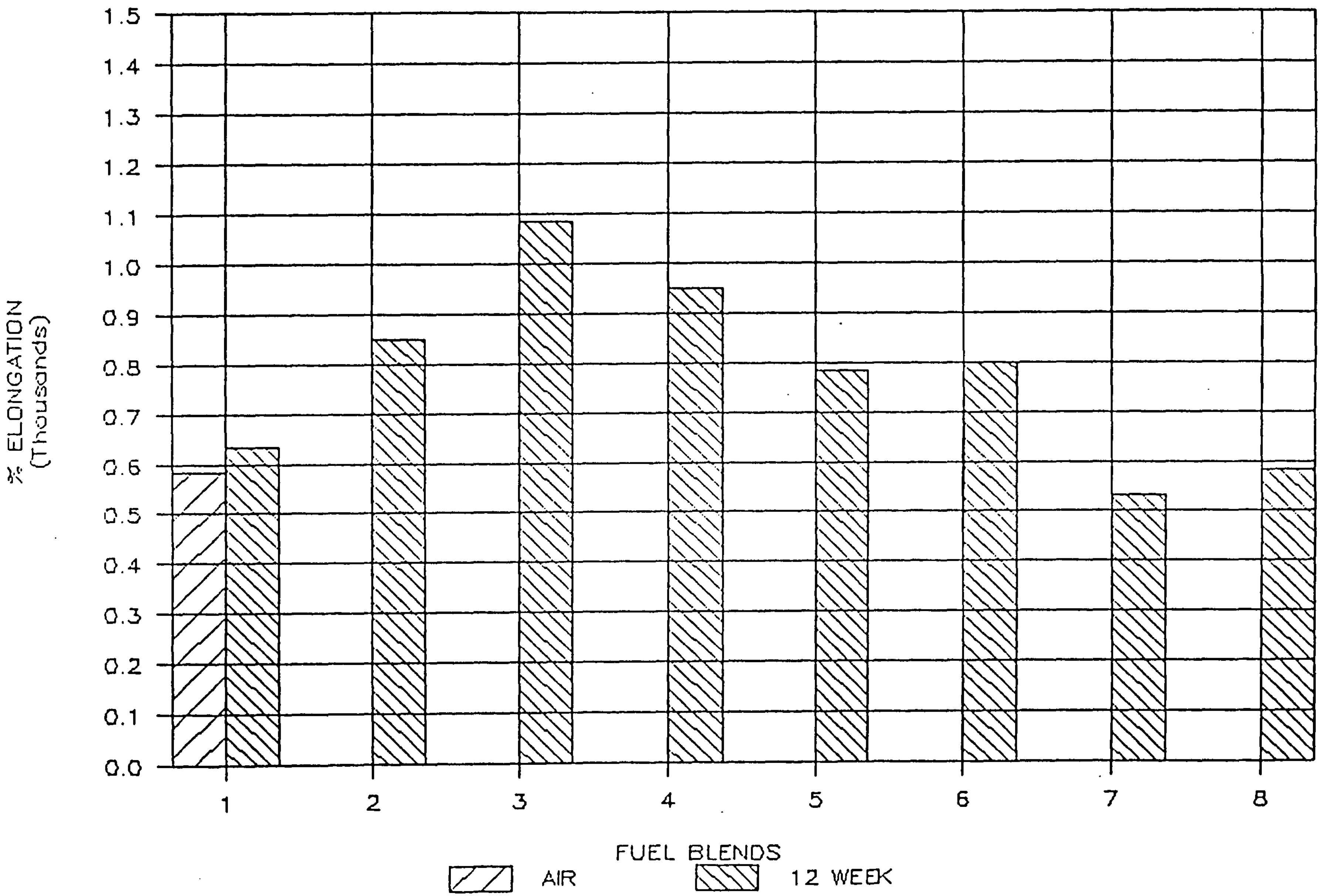
ETHYL FUEL COMPATIBILITY—VITON (lo)

TWELVE WEEK DATA



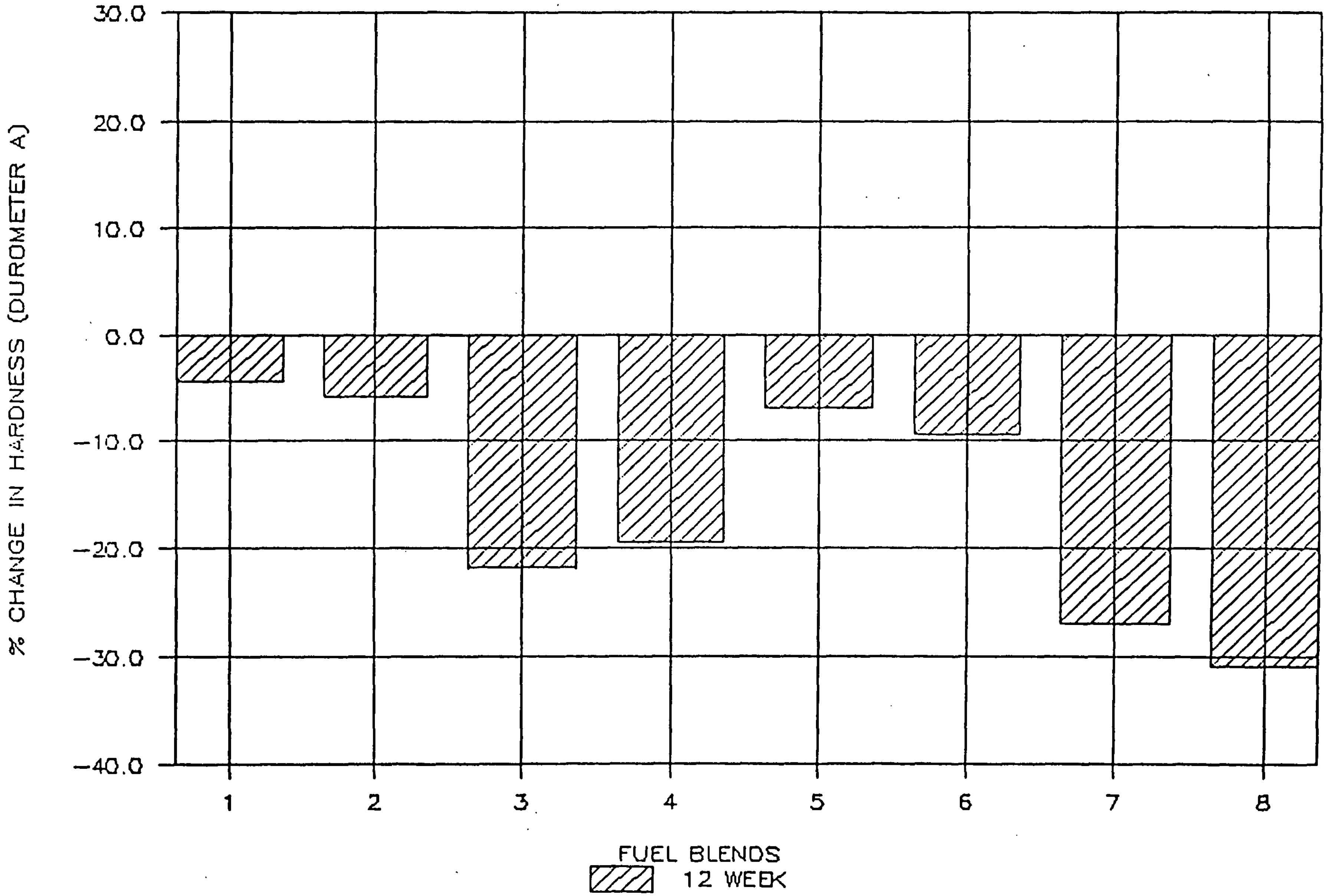
ETHYL FUEL COMPATIBILITY—URETHENE

AIR AND TWELVE WEEK DATA



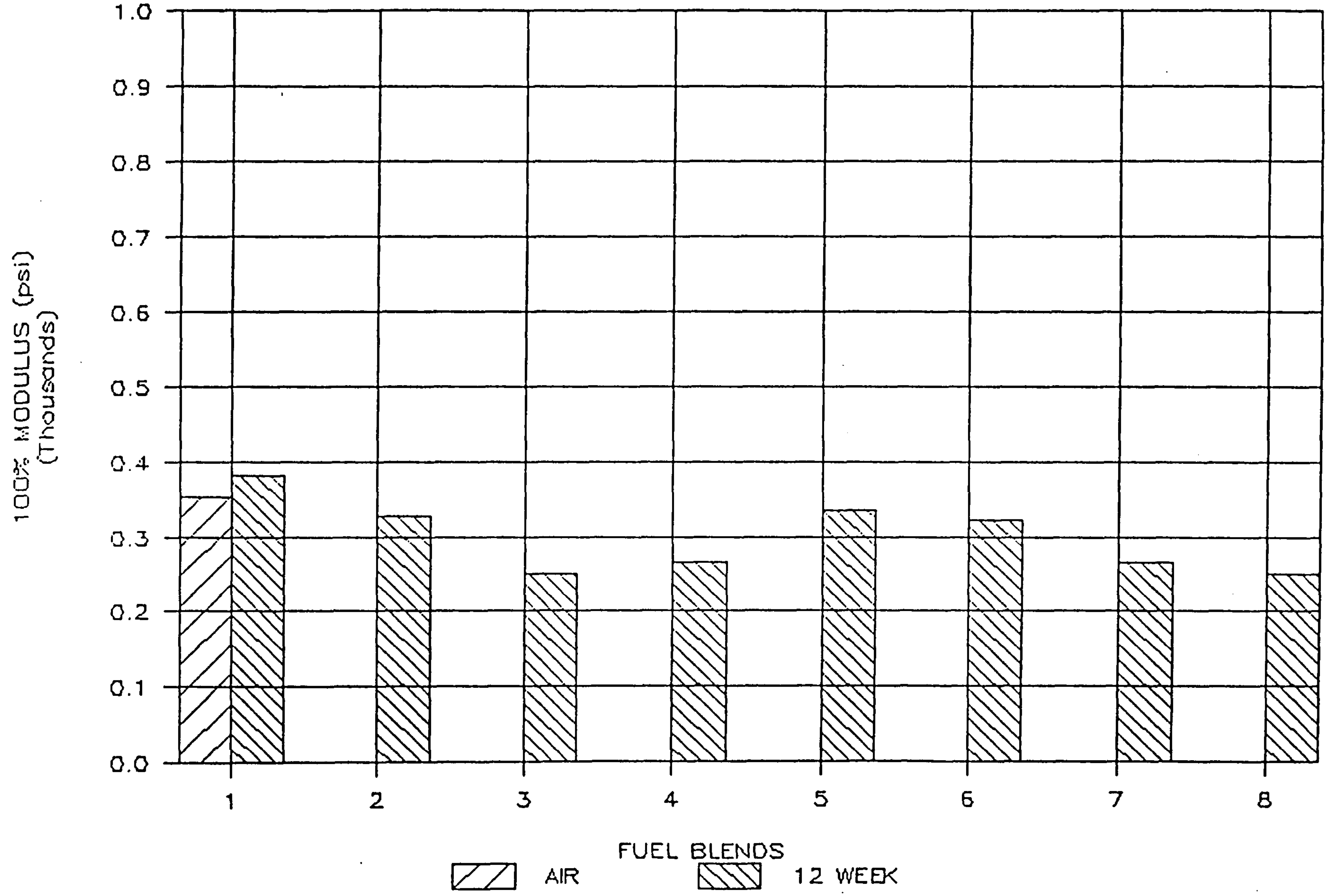
ETHYL FUEL COMPATIBILITY—URETHENE

TWELVE WEEK DATA



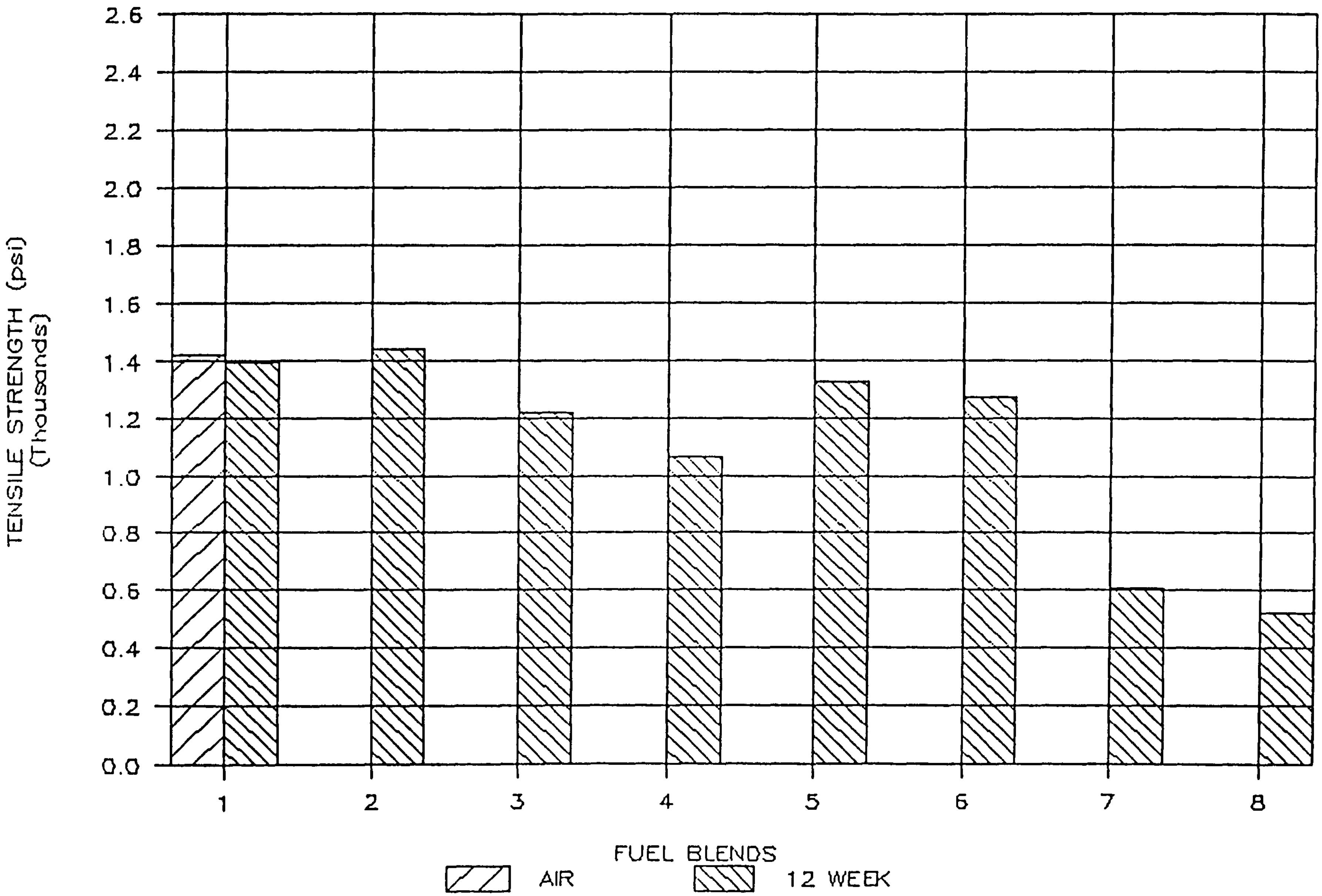
ETHYL FUEL COMPATIBILITY—URETHENE

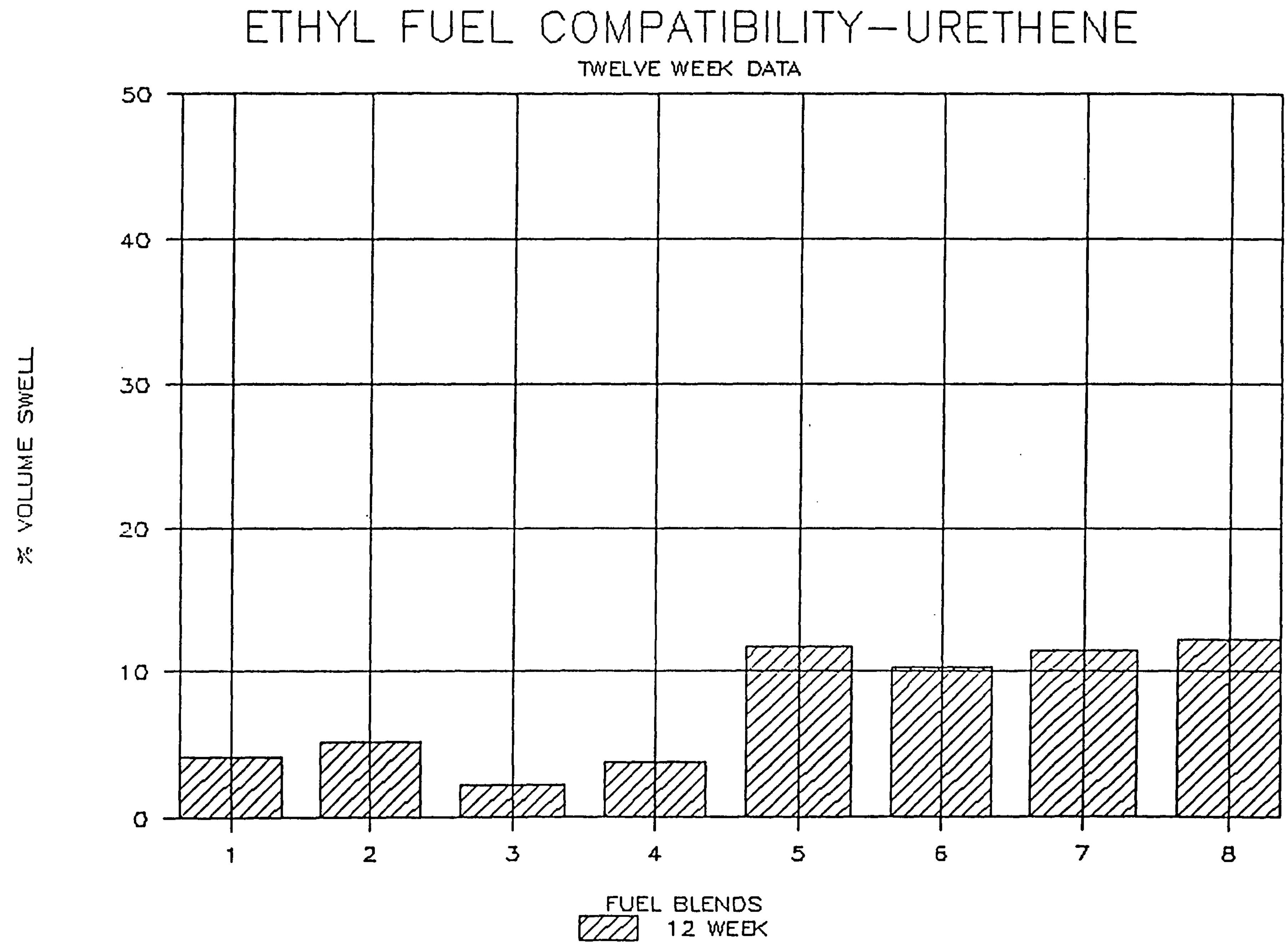
AIR AND TWELVE WEEK DATA



ETHYL FUEL COMPATIBILITY–URETHENE

AIR AND TWELVE WEEK DATA





ETHYL FUEL COMPATIBILITY—URETHENE
TWELVE WEEK DATA
% VOLUME SWELL
50
40
30
20
10
0
1
2
3
4
5
6
7
8
FUEL BLENDS
12 WEEK

PLASTICS

TWELVE WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE PLASTIC	FUEL BLEND	TENSILE	% ELONG	% THICKNESS CHANGE	% VOLUME SWELL	% WEIGHT CHANGE
NYLON 6/6	1	10200.0	26.5	-2.3	0.0	0.5
#1731	2	9920.6	27.0	-3.0	0.0	1.1
	3	9409.5	32.0	-2.3	0.0	2.3
	4	9609.5	31.5	-3.0	0.0	2.3
	5	10060.3	25.0	-0.8	0.0	1.0
	6	9968.3	30.0	-1.5	0.0	2.2
	7	9377.8	32.0	-0.8	0.0	3.4
	8	9301.6	35.0	-1.5	0.0	2.8

TYPE PLASTIC	FUEL BLEND	TENSILE	% ELONG	% THICKNESS CHANGE	% VOLUME SWELL	% WEIGHT CHANGE
HDPE	1	3641.3	36.5	0.0	0.0	3.7
#1730	2	3625.4	40.0	-0.8	0.0	4.1
	3	3565.1	38.5	-1.6	0.0	3.4
	4	3609.5	38.5	-1.6	0.0	3.4
	5	3504.8	36.5	0.0	0.0	4.7
	6	3565.1	33.0	0.0	0.0	6.1
	7	3488.9	43.0	-1.6	0.0	5.6
	8	3488.9	40.0	-1.6	0.0	5.1

TYPE PLASTIC	FUEL BLEND	TENSILE	% ELONG	% THICKNESS CHANGE	% VOLUME SWELL	% WEIGHT CHANGE
DELRIN	1	10850.8	40.0	-1.5	0.0	-0.1
#1732	2	10679.4	48.0	-1.5	0.0	0.0
	3	6790.5	86.5	-1.5	0.0	5.9
	4	6619.0	80.0	-1.5	0.0	6.3
	5	8774.6	51.5	-2.9	0.0	1.0
	6	10990.5	43.5	-3.7	0.0	-0.4
	7	6571.4	100.0	-1.5	0.0	6.9
	8	6403.2	95.0	-1.5	0.0	7.0

TWELVE WEEK DATA

(Averages of two specimens per fuel blend used for graphing)

TYPE PLASTIC	FUEL BLEND	TENSILE	% ELONG	% THICKNESS CHANGE	% VOLUME SWELL	% WEIGHT CHANGE
NYLON 11	1	4023.7	89.0	0.0	3.3	1.5
#1832	2	3939.3	89.0	0.0	3.3	1.5
	3	3591.6	89.0	0.0	5.7	2.7
	4	3561.7	89.0	0.0	6.0	2.5
	5	4119.3	89.0	0.0	3.1	1.2
	6	3958.8	96.5	0.0	3.5	1.4
	7	3561.7	89.0	0.0	7.7	4.0
	8	3572.0	89.0	0.0	8.1	4.4

TYPE PLASTIC	FUEL BLEND	TENSILE	% ELONG	% THICKNESS CHANGE	% VOLUME SWELL	% WEIGHT CHANGE
PETG	1	5080.0	18.5	0.0	0.0	4.5
#1833	2	4880.0	10.0	14.3	0.0	10.2
	3	5040.0	20.0	14.3	0.0	8.5
	4	4480.0	12.0	14.3	0.0	8.7
	5	3920.0	10.0	21.4	0.0	9.0
	6	3920.0	5.0	14.3	0.0	10.7
	7	3320.0	7.0	14.3	0.0	9.7
	8	4120.0	17.0	14.3	0.0	9.4

ETHYL FUEL COMPATABILITY TEST

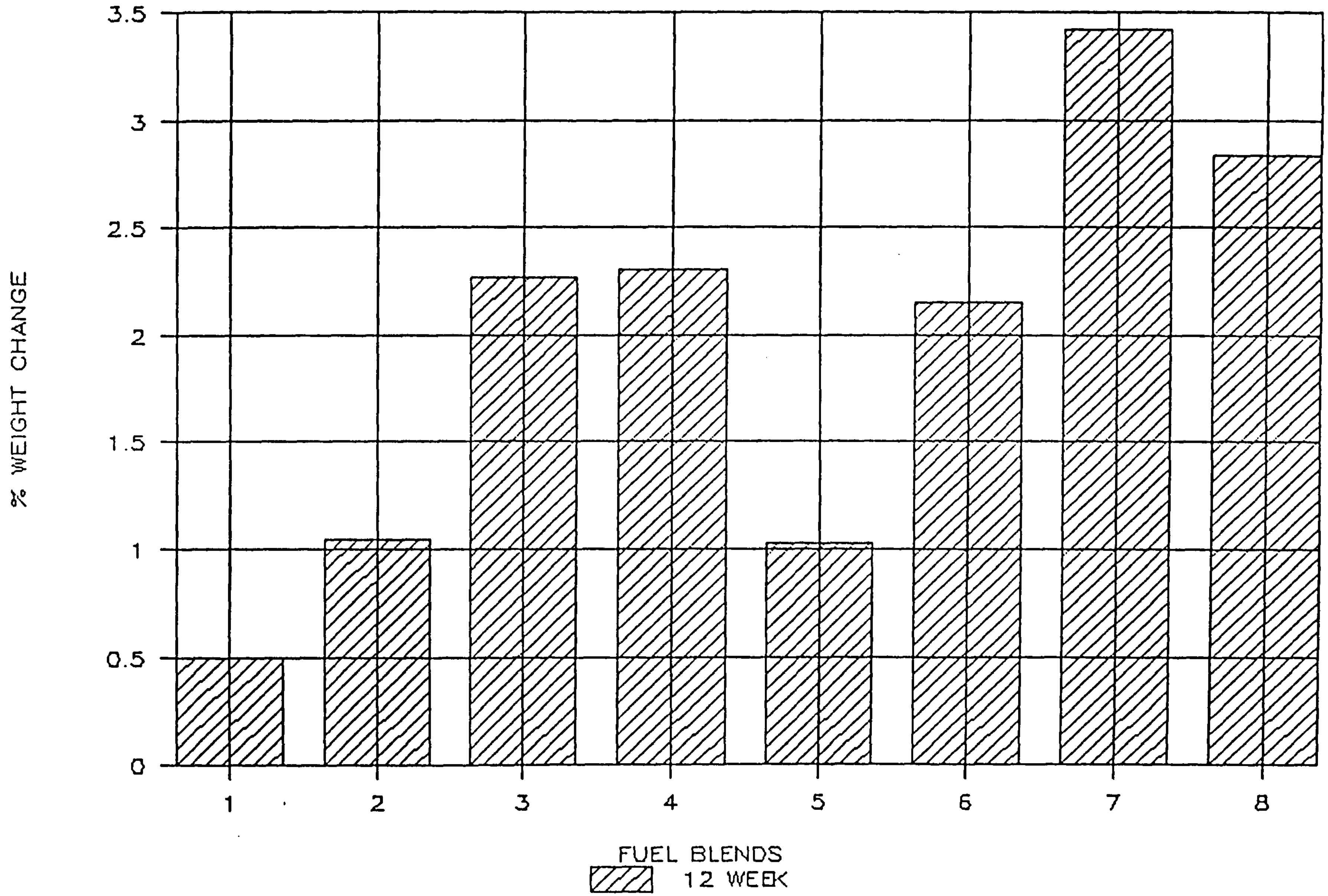
TWELVE WEEK DATA

TYPE PLASTIC	SPECIME NO.	FUEL BLEND	TENSILE	% ELONG	% THICKNESS CHANGE	% VOLUME SWELL	% WEIGHT CHANGE	THICKNESS INITIAL	THICKNESS FINAL	WEIGHT INITIAL	WEIGHT FINAL	H20 WEIGHT INITIAL	H20 WEIGHT FINAL
DELRIN	6	1	10787.3	40	-1.4706		0.0918	0.068	0.067	3.4856	3.4888		
#1732	12	2	10723.81	43	-1.4706		-0.0569	0.068	0.067	3.5179	3.5159		
	18	3	6730.16	80	-1.4706		5.8246	0.068	0.067	3.4938	3.6973		
	24	4	6603.17	87	-1.4706		6.3731	0.068	0.067	3.5195	3.7438		
	30	5	8806.35	50	-2.9412		0.9787	0.068	0.066	3.5047	3.5390		
	36	6	10977.78	37	-4.4118		-0.5520	0.068	0.065	3.4961	3.4768		
	42	7	6571.43	90	-1.4706		6.9543	0.068	0.067	3.5230	3.7680		
	48	8	6419.05	83	-1.4706		7.0621	0.068	0.067	3.5046	3.7521		
NYLON 11	5	1	4008.23	89		3.2699	1.4984			11.0652	11.2310	0.49	0.31
#1832	11	2	3888.89	89		3.2675	1.4968			11.0701	11.2358	0.49	0.31
	17	3	3687.24	89		5.6315	2.6759			11.0840	11.3806	0.49	0.19
	23	4	3516.46	89		6.0366	2.6022			11.0522	11.3398	0.49	0.14
	29	5	4119.34	89		3.1658	1.2281			11.1225	11.2591	0.49	0.29
	35	6	3938.27	104		3.3964	1.4329			11.0334	11.1915	0.49	0.29
	41	7	3576.13	89		6.6019	2.9852			11.1248	11.4569	0.49	0.12
	47	8	3557.61	89		8.1103	4.4439			10.9027	11.3872	0.49	0.13
NYLON 11	6	1	4039.09	89		3.2344	1.5541			11.0609	11.2328	0.49	0.32
#1832	12	2	3987.65	*74		3.3510	1.4762			11.0283	11.1911	0.50	0.31
	18	3	3495.88	89		5.7127	2.6439			11.0140	11.3052	0.49	0.18
	24	4	3607.00	89		5.9162	2.4698			10.9967	11.2683	0.49	0.14
	30	5	4119.34	89		3.1225	1.1784			11.0744	11.2049	0.49	0.29
	36	6	3979.42	89		3.6888	1.4535			11.0977	11.2590	0.49	0.26
	42	7	3547.33	*148		8.7618	5.1020			11.0095	11.5712	0.49	0.13
	48	8	3586.42	89		8.0352	4.4520			11.1456	11.6418	0.49	0.13
PETG	5	1	4720	17	0.0000		-0.3557	0.007	0.007	0.2811	0.2801		
#1833	11	2	5040	10	14.2857		9.3468	0.007	0.008	0.2771	0.3030		
	17	3	5040	20	14.2857		8.3661	0.007	0.008	0.2546	0.2759		
	23	4	5040	17	14.2857		8.4252	0.007	0.008	0.2540	0.2754		
	29	5	3920	7	28.5714		9.0642	0.007	0.009	0.2725	0.2972		
	35	6	3920	3	14.2857		11.3993	0.007	0.008	0.2737	0.3049		
	41	7	3520	7	14.2857		10.0692	0.007	0.008	0.2602	0.2864		
	47	8	3920	17	14.2857		9.5349	0.007	0.008	0.2580	0.2826		
PETG	6	1	5440	20	0.0000		9.3058	0.007	0.007	0.2665	0.2913		
#1833	12	2	4720	10	14.2857		11.0303	0.007	0.008	0.2611	0.2899		
	18	3	5040	20	14.2857		8.7246	0.007	0.008	0.2556	0.2779		
	24	4	3920	7	14.2857		8.9116	0.007	0.008	0.2637	0.2872		
	30	5	3920	13	14.2857		8.9494	0.007	0.008	0.2570	0.2800		
	36	6	3920	7	14.2857		9.9565	0.007	0.008	0.2531	0.2783		
	42	7	3120	7	14.2857		9.2780	0.007	0.008	0.2576	0.2815		
	48	8	4320	17	14.2857		9.2434	0.007	0.008	0.2564	0.2801		

(*) DATA NOT SUMMARIZED

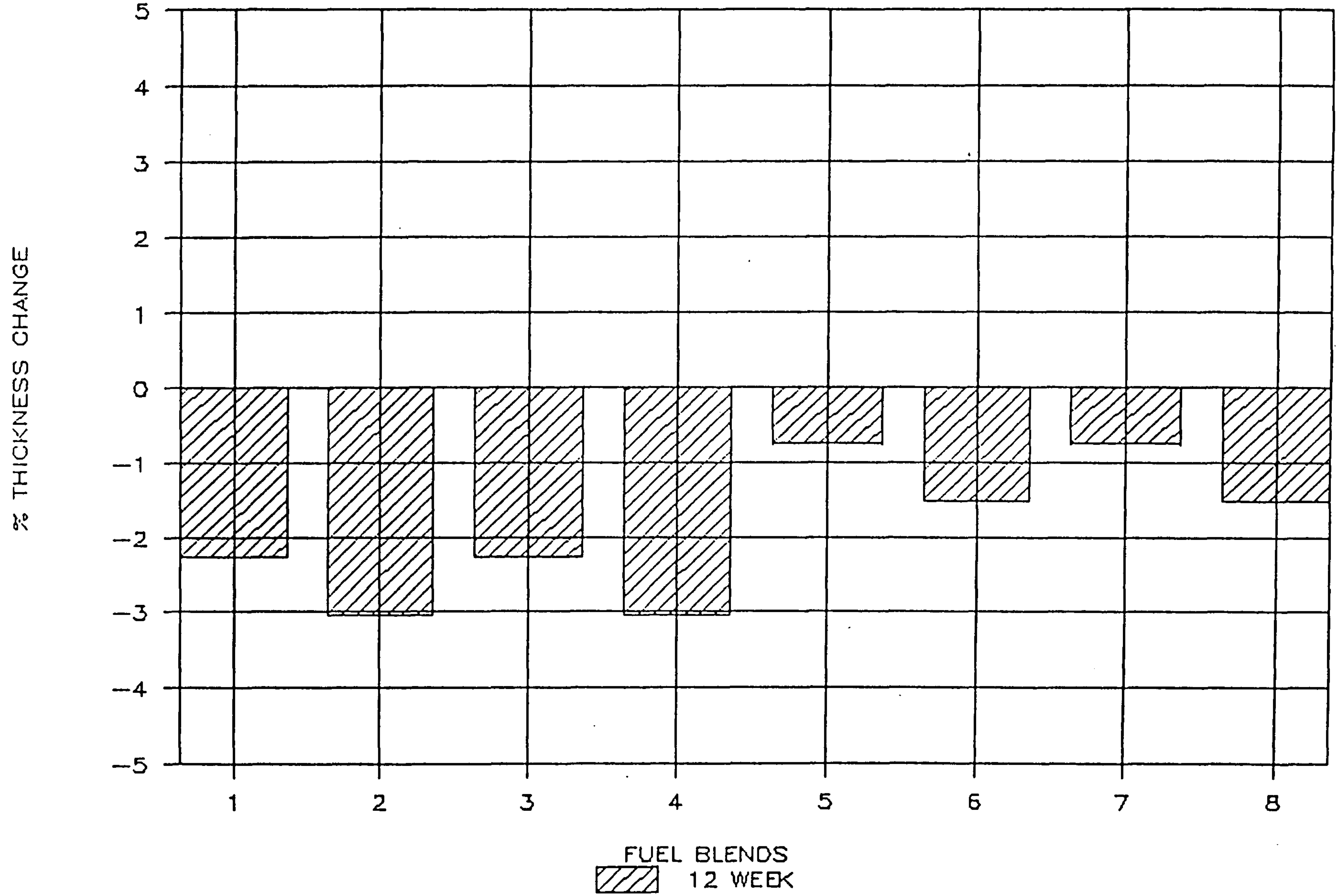
ETHYL FUEL COMPATIBILITY—NYLON 6/6

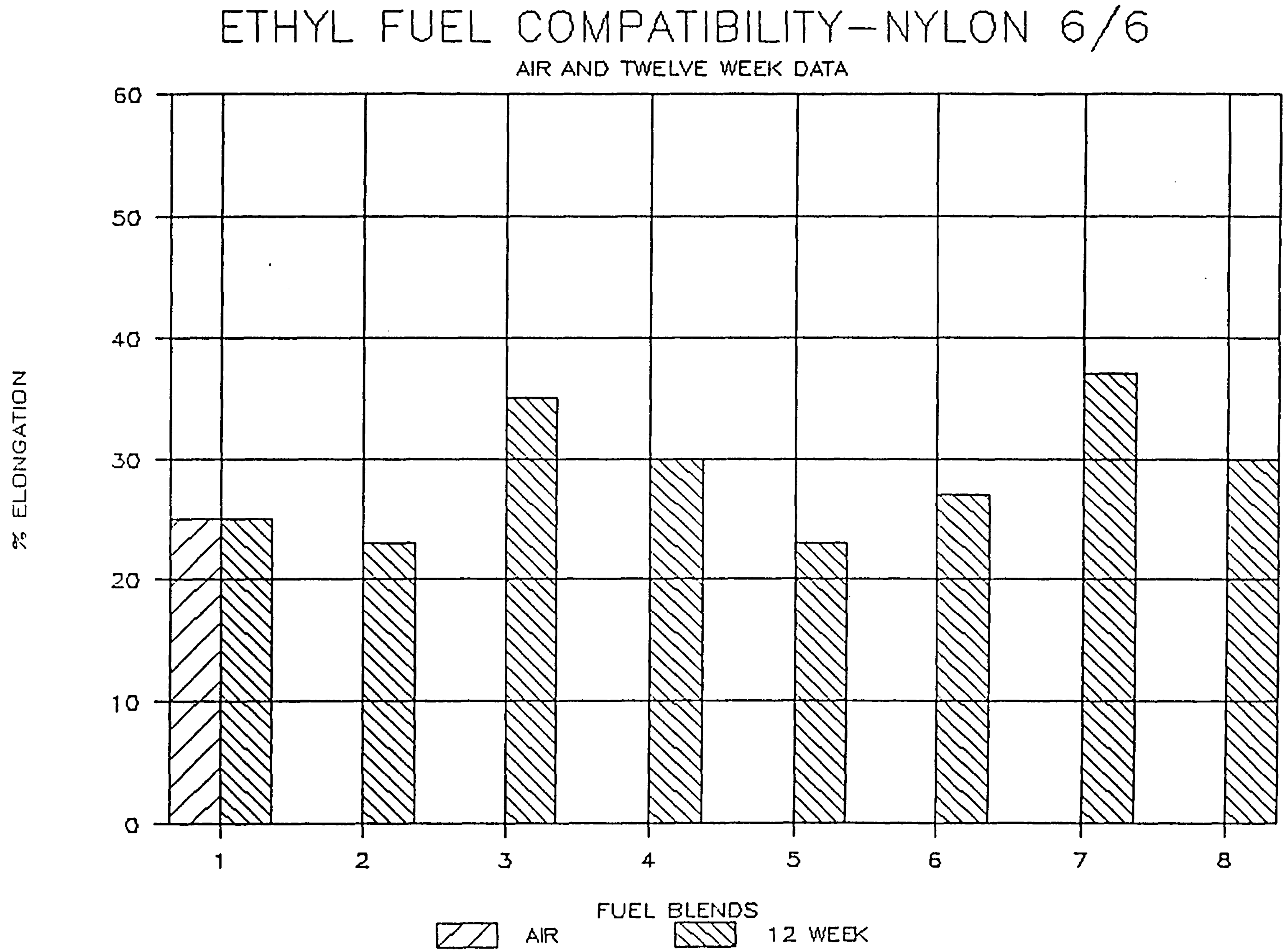
TWELVE WEEK DATA



ETHYL FUEL COMPATIBILITY—NYLON 6/6

TWELVE WEEK DATA

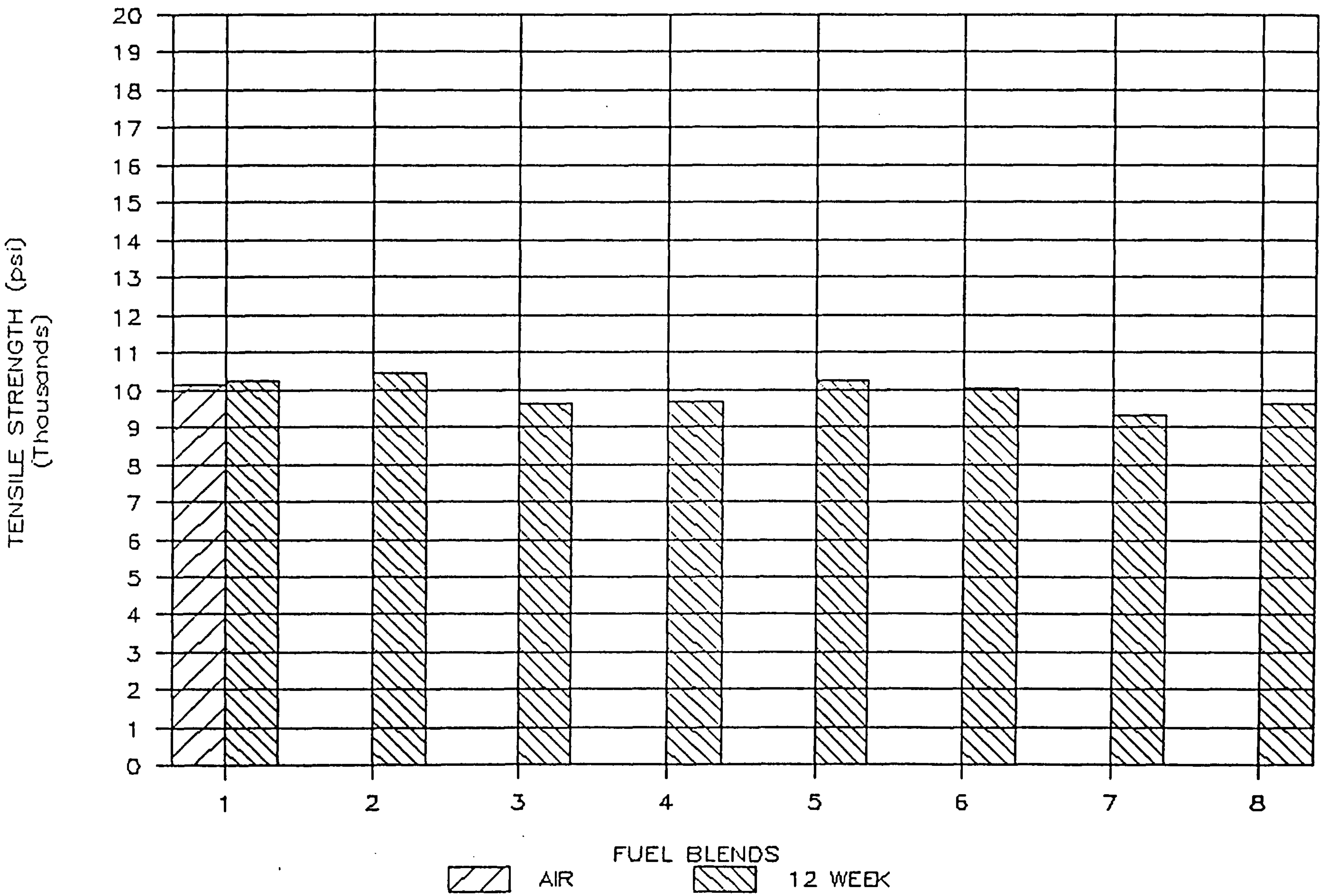


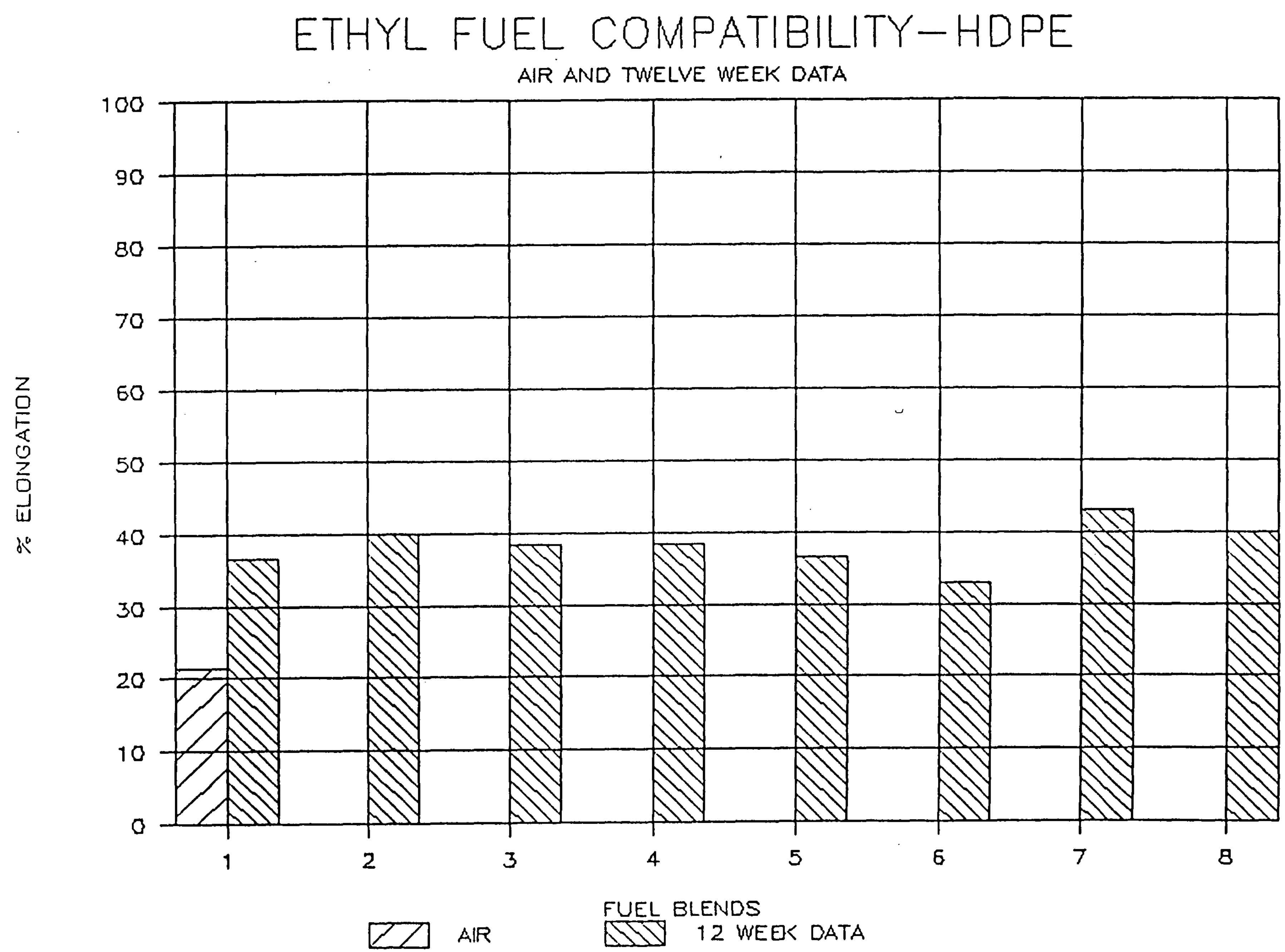


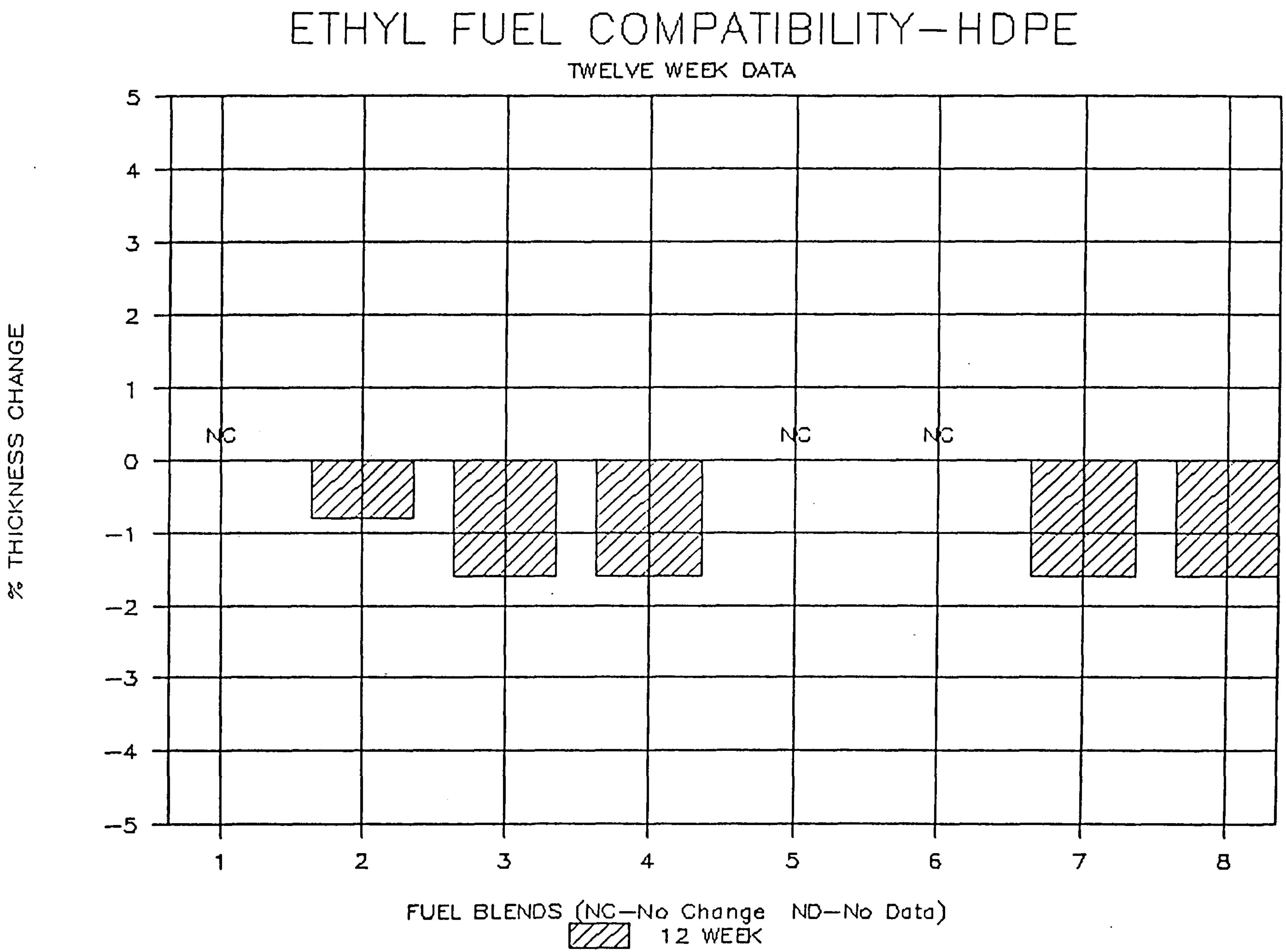
ETHYL FUEL COMPATIBILITY-NYLON 6/6
AIR AND TWELVE WEEK DATA
% ELONGATION
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

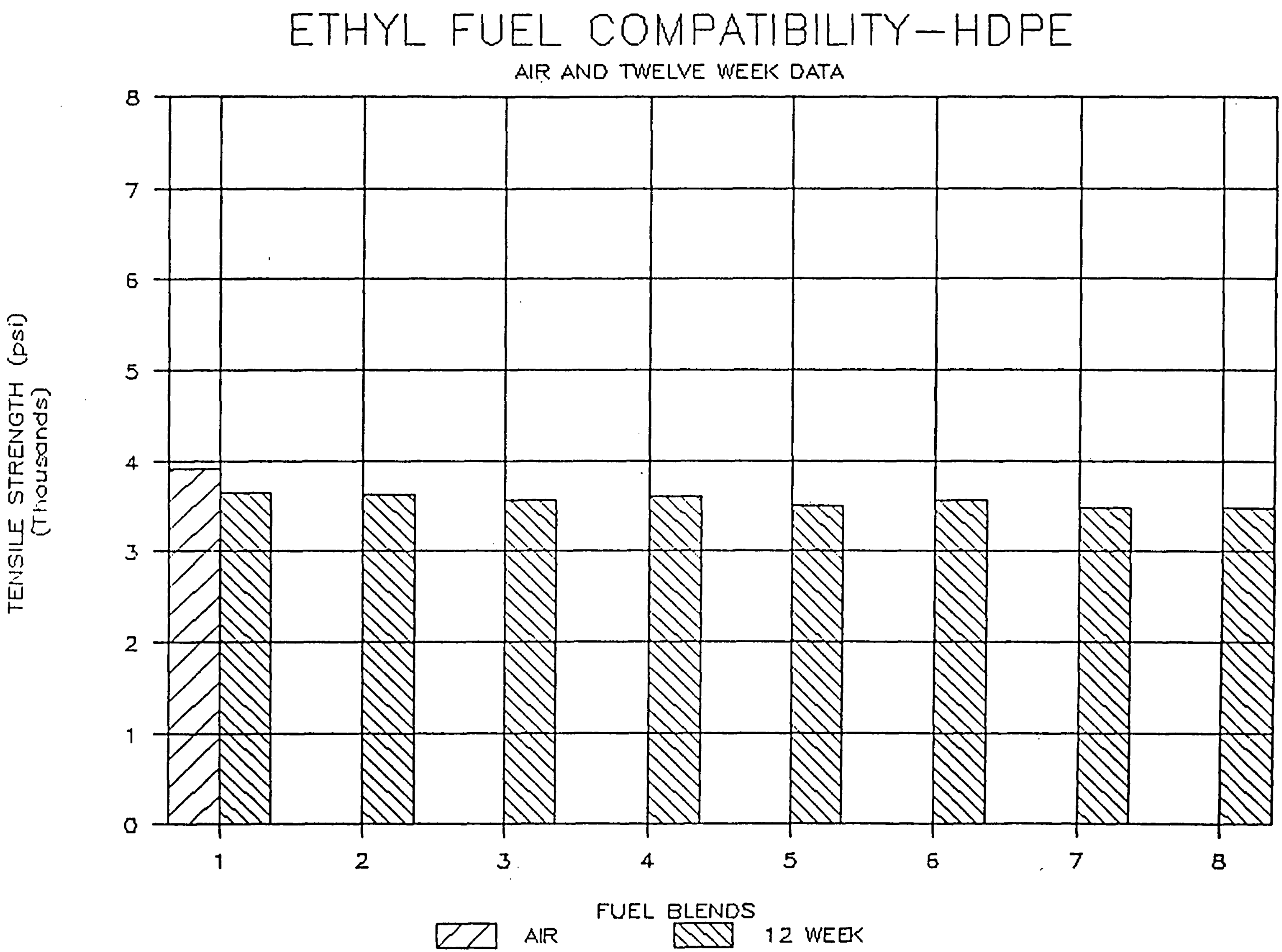
ETHYL FUEL COMPATIBILITY—NYLON 6/6

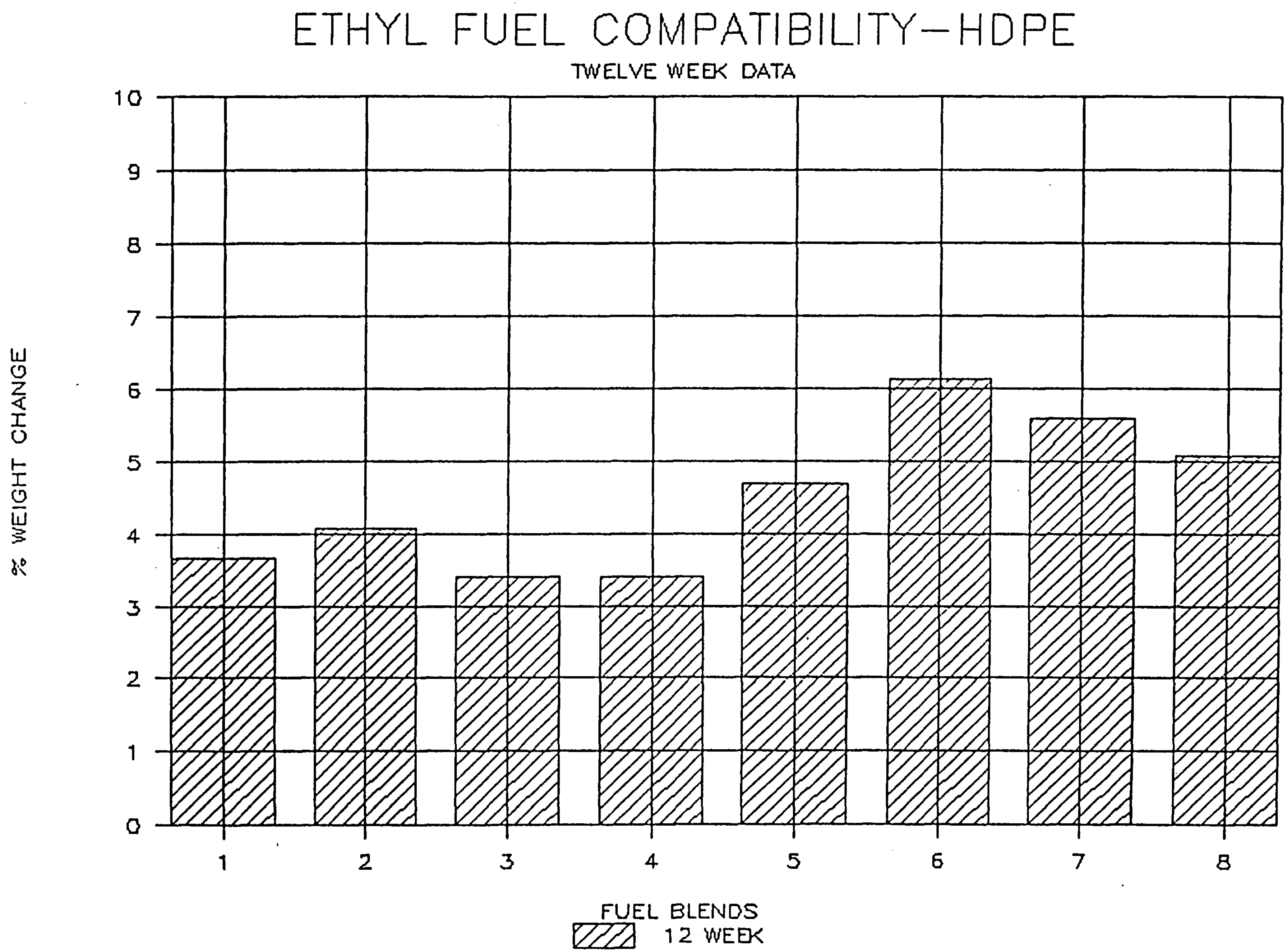
AIR AND TWELVE WEEK DATA




ETHYL FUEL COMPATIBILITY—HDPE
AIR AND TWELVE WEEK DATA
% ELONGATION
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK DATA

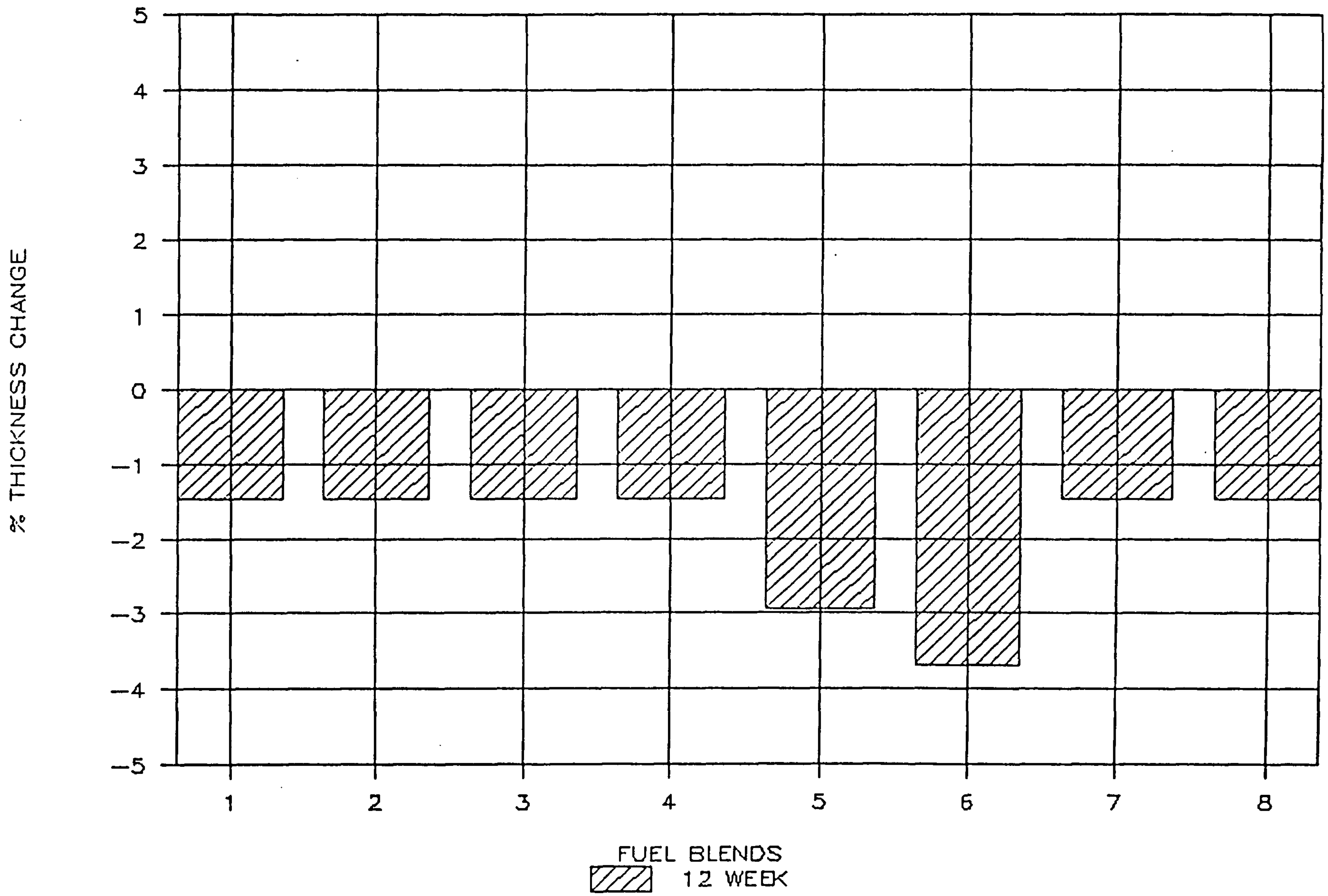

ETHYL FUEL COMPATIBILITY-HDPE
TWELVE WEEK DATA
% THICKNESS CHANGE
5
4
3
2
1
0
-1
-2
-3
-4
-5
NC
NC
NC
1
2
3
4
5
6
7
8
FUEL BLENDS (NC-No Change ND-No Data)
12 WEEK

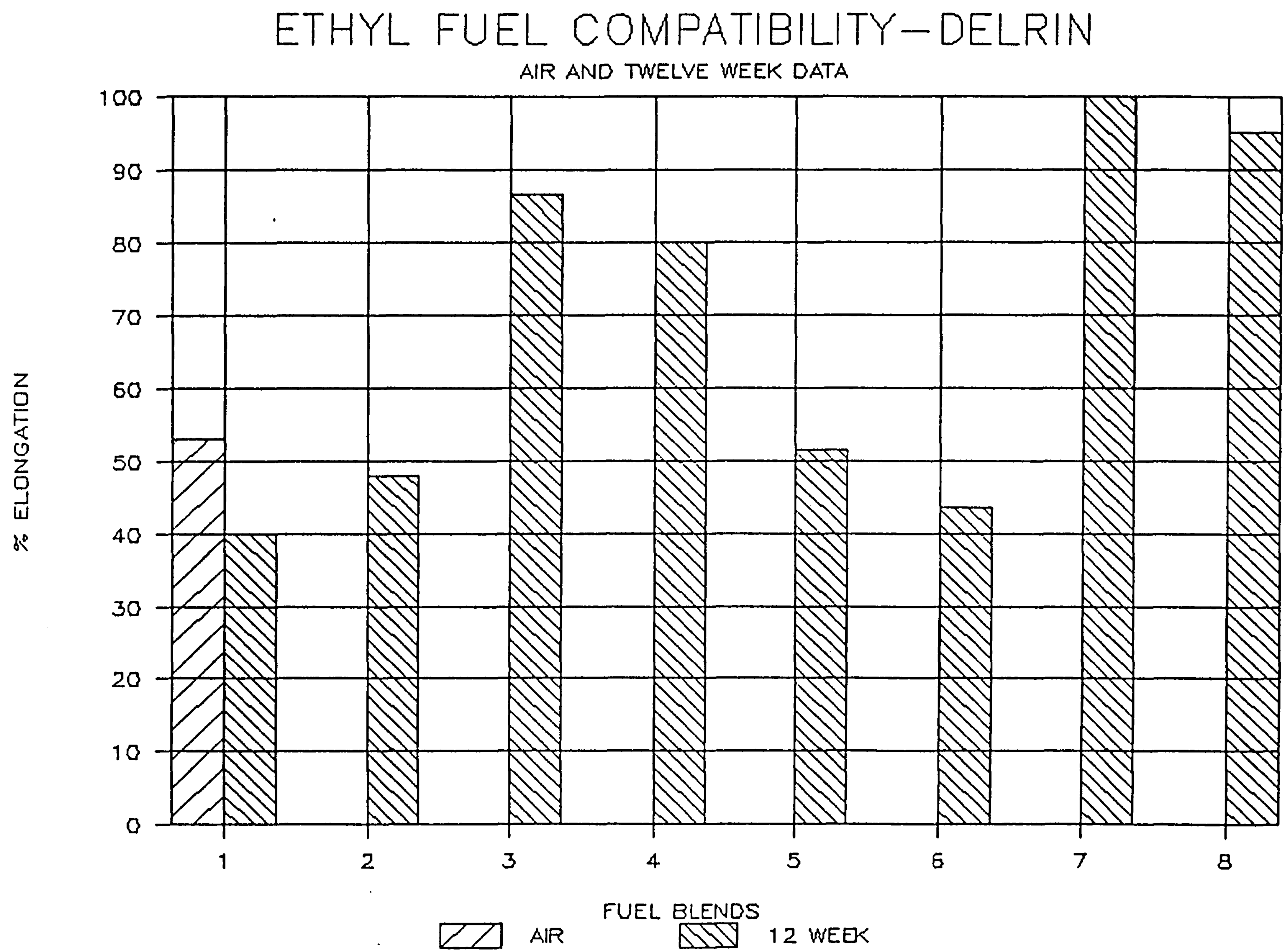

ETHYL FUEL COMPATIBILITY—HDPE
AIR AND TWELVE WEEK DATA
TENSILE STRENGTH (psi)
(Thousands)
0
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK


ETHYL FUEL COMPATIBILITY–HDPE
TWELVE WEEK DATA
% WEIGHT CHANGE
0
1
2
3
4
5
6
7
8
9
10
1
2
3
4
5
6
7
8
FUEL BLENDS
12 WEEK

ETHYL FUEL COMPATIBILITY–DELRIN

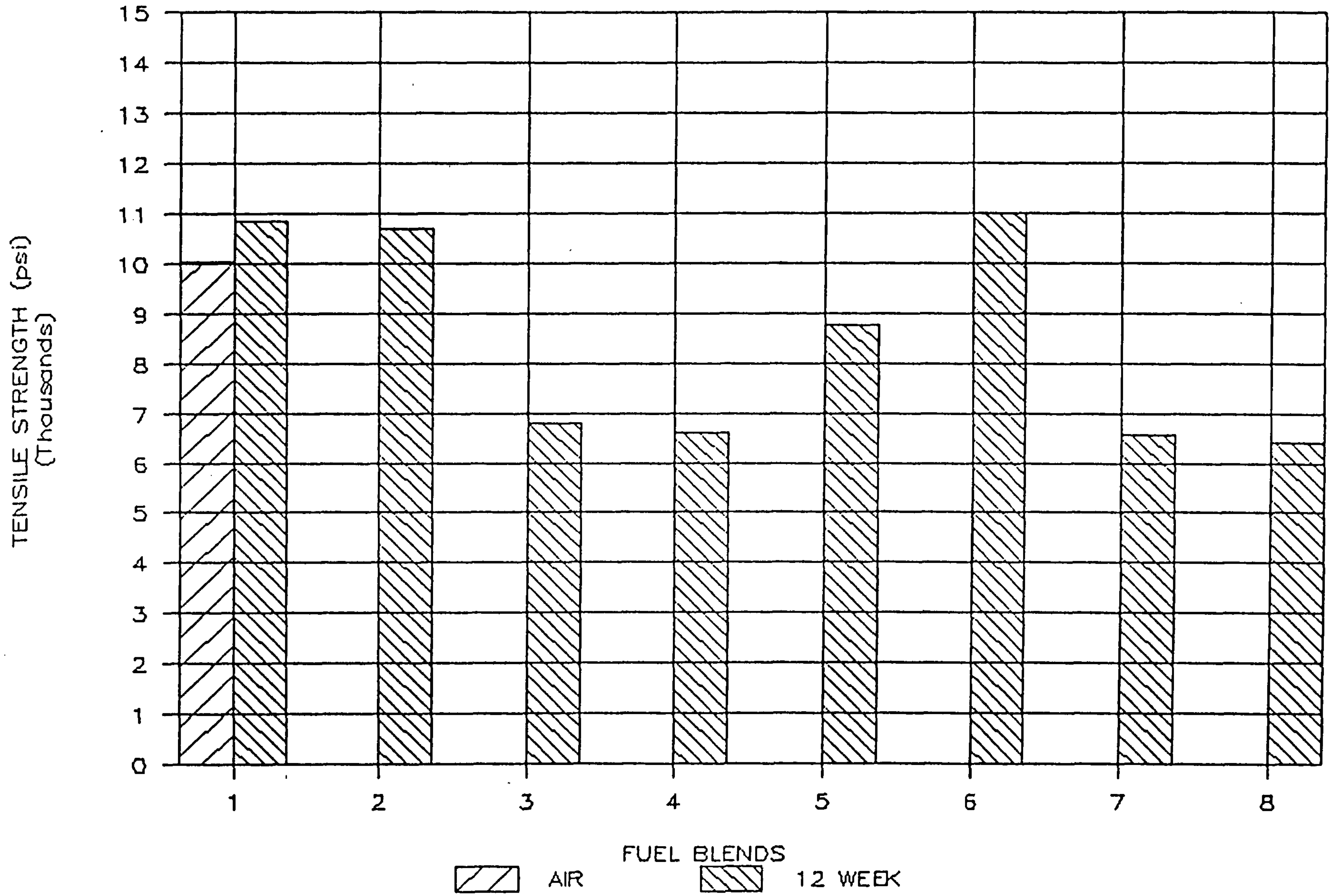
TWELVE WEEK DATA




ETHYL FUEL COMPATIBILITY—DELRIN
AIR AND TWELVE WEEK DATA
% ELONGATION
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
FUEL BLENDS
AIR
12 WEEK

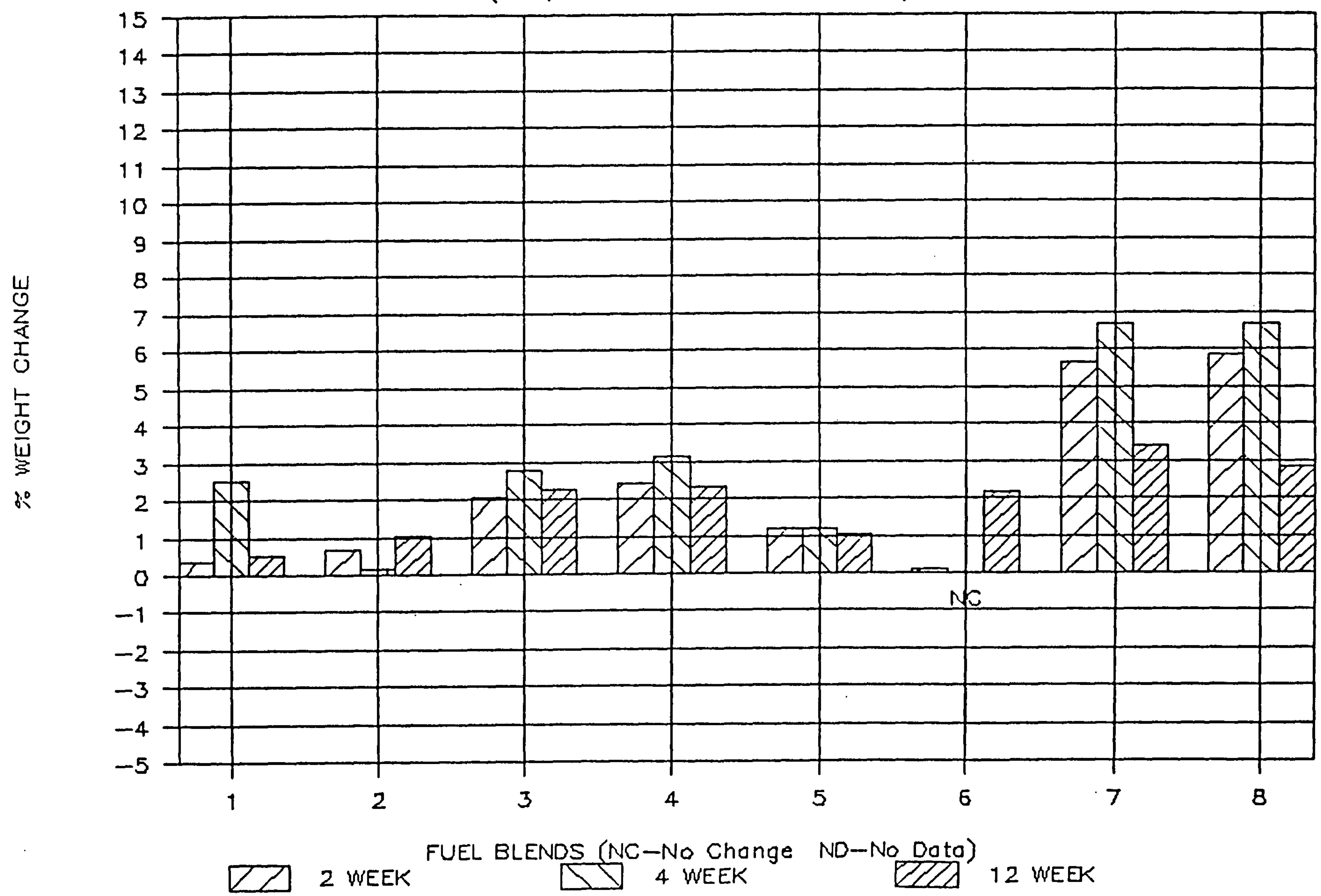
ETHYL FUEL COMPATIBILITY–DELRIN

AIR AND TWELVE WEEK DATA



ETHYL FUEL COMPATIBILITY—DELRIN

(TWO, FOUR & TWELVE WEEK DATA)



ETHYL FUEL COMPATIBILITY–NYLON 11

(AIR, TWO, FOUR & TWELVE WEEK DATA)